On the Macroeconomic Implications of Firm Dynamics, Banking, and Reputation

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1 Introduction

"The history of modern macroeconomics starts in 1936, with the publication of Keynes' *General Theory of Employment, Interest, and Money*" [Blanchard (2008, p. 576)]. Thereafter, many new ideas and solution concepts for macroeconomic problems emerged, disappeared, and were combined in order to appropriately describe macroeconomic phenomena.[1] Nowadays, New Keynesian frameworks are the workhorse models for monetary macroeconomics. These models combine elements of the Real Business Cycle literature such as rational expectations, microfoundations, and the concept of the dynamic stochastic general equilibrium (henceforth: DSGE) with Keynesian elements such as nominal price rigidities and market imperfections. However, we claim that New Keynesian models still have some weaknesses. Therefore, this thesis contributes to the literature by providing – to our mind – important extensions of the baseline New Keynesian model and by analyzing new aspects of monetary and fiscal policy. In particular, we identify the following *four weaknesses*.

First, the baseline New Keynesian model does not incorporate a frictional financial sector. However, empirical studies as for instance Aliaga-Díaz and Olivero (2010) or Santos and Winton (2008) show that in particular banks and their non-stationary price-cost margins are of great interest for business cycle dynamics. In line with this finding, Jermann and Quadrini (2009) show that the introduction of a financial sector leads to an important propagation of macroeconomic volatility.

Second, a simplifying assumption of the baseline New Keynesian model is that the mass of firms is constant (and normalized to one). However, there is empirical evidence for instance provided by Devereux, Head, and Lapham (1996) that the number of operating firms significantly co-moves with GDP. Moreover, amongst others Campbell (1998) shows that firm entries and in particular firm exits significantly contribute to business cycle dynamics. The recent literature however neglects simultaneous endogenous firm entry and exit.

Third, monetary policy follows a simple instrument rule of Taylor (1993) type in the baseline New Keynesian model. In reality, central banks however do not strictly rely on commitment strategies. Instead, they deviate from their rules for instance in the presence of large shocks. The topic of policy switching regimes and the resulting consequences for the credibility of central banks are already discussed in the famous study of Barro and Gordon (1983a,b). However, the authors do not consider any

[1] See amongst others Woodford (2009), Blanchard (2008), and Galí and Gertler (2007) for an overview of the history of modern macroeconomics.

demand side effects of the economy in their approach. Moreover, the authors assume for the sake of simplicity that the central bank can directly (and perfectly) control the inflation rate.

Fourth, traditional New Keynesian approaches analyze the impacts of fiscal stimuli on standard measures of economic activity such as GDP, employment, and capital investment [see amongst others Linnemann and Schabert (2003)] but neglect their impact on the extensive margin, i.e. the mass of firms operating in the market. However, a recent literature highlights the role of an endogenous mass of firms as an important propagation and amplification mechanism for business cycle fluctuations [see Bilbiie, Ghironi, and Melitz (2007a,b) and Bergin and Corsetti (2008)]. In particular, this amplification effect potentially gives rise to larger fiscal multipliers.

This thesis is structured as follows. In Section 1.1, we shortly present the baseline New Keynesian model including the basic assumptions. The resulting problems, potential solutions, and the contribution of this thesis to the macroeconomics literature are discussed in Section 1.2.

The main part of this thesis is divided into *two parts*. In *Part One* consisting of Chapter 2 and 3, we contribute to the literature by providing – to our mind – important new *extensions of the baseline New Keynesian model*. In particular, we develop a New Keynesian model incorporating an oligopolistic banking sector with endogenous bank entry in *Chapter 2*. Within this framework, we conduct an impulse response analysis and evaluate the model by comparing the generated second moments with the data. In *Chapter 3*, we develop a New Keynesian model incorporating an endogenous mass of firms allowing for simultaneous entry and exit of heterogeneous firms. This chapter includes the investigation of the resulting impulse responses, a second moment analysis, and an empirical part concerning a Phillips curve estimation.

In *Part Two* consisting of Chapter 4 and 5, we contribute to the literature by providing new aspects of *monetary and fiscal policy*. More precisely, the aim of *Chapter 4* is to solve the inconsistency problem à la Barro and Gordon within a standard New Keynesian model and to derive time-consistent interest rate rules of Taylor-type. In *Chapter 5*, we estimate a DSGE model with capital in production and endogenous firm entry using Bayesian techniques. Within this framework, we investigate the macroeconomic effects of different fiscal interventions.

The last chapter (*Chapter 6*) concludes and provides an outlook for future research.

1.1 The Baseline New Keynesian Model

The baseline New Keynesian model[2] represents a closed economy framework. Beside the central bank, the model consists of three types of agents: households, intermediate good producers (or: firms), and final good producers (or: retailers). Within each type of economic actors, agents are homogeneous.

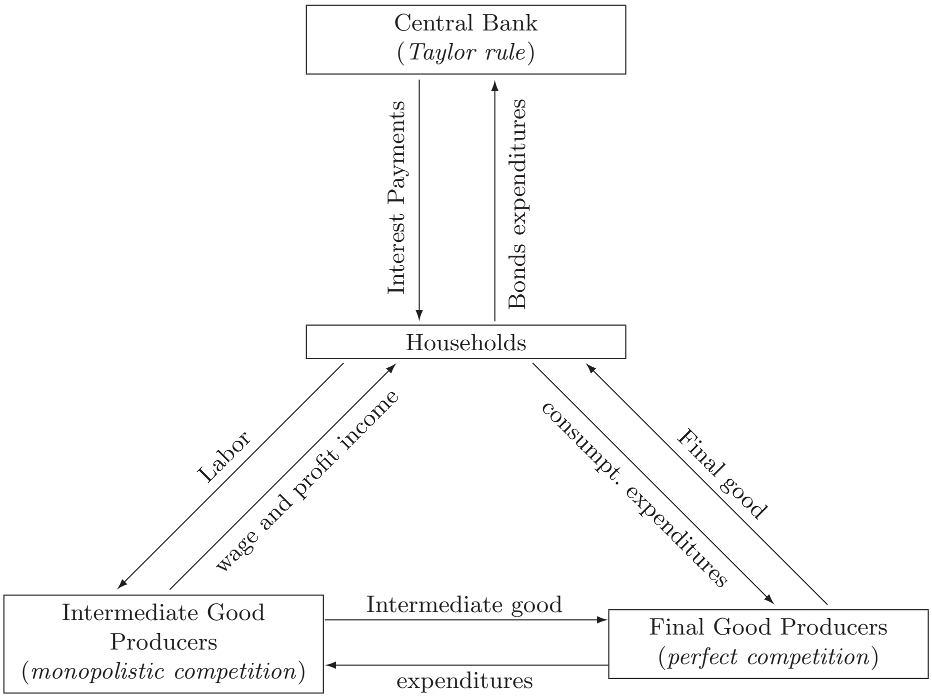

Figure 1.1: *Model structure of the baseline New Keynesian model*

Households invest in interest bearing bonds, consume a bundle of goods, and supply labor to firms. Labor markets are complete. Each firm produces a differentiated good using labor.[3] Firms act under monopolistic competition. This assumption ensures that firms act as price setters as opposed to price takers. Firms sell their differentiated goods to the retailers being faced with a sticky price setting mechanism as introduced by Calvo (1983).[4] The generated profits are transferred to the households. Retailers simply bundle the intermediate goods to a final good and sell it under perfectly competitive conditions to the households. The monetary authority

[2] For an excellent introduction to New Keynesian Macroeconomics see amongst others Galí (2008) and Wohltmann and Winkler (2008, 2009).

[3] Though capital accumulation is a key element of the RBC literature, it is absent in the baseline New Keynesian model. However, it can easily be extended by capital in production.

[4] When neglecting trend inflation and real wage rigidities, the results do not change when alternatively introducing quadratic price adjustment costs in the spirit of Rotemberg (1982) to the model. However, Ascari and Merkl (2009) show that when incorporating these features the resulting adjustment dynamics under Calvo and Rotemberg pricing significantly diverge in a *non-linear* framework [see also Ascari and Rossi (forthcoming)].

does not directly control for inflation but for the nominal interest rate by following an instrument rule of Taylor (1993) type. Figure 1.1 depicts the model structure of the baseline New Keynesian model.

1.2 Problems and Potential Solutions

After having described the baseline New Keynesian model, we will now show up some weaknesses of New Keynesian models and potential solutions. Thereby, we will sketch the outline of this thesis and emphasize its contribution to the New Keynesian literature.

Financial Frictions

The baseline New Keynesian model does not incorporate a frictional financial sector. However, as Gertler (1988) highlights, there already exists a long-standing tradition in macroeconomic theory that emphasizes a central role to financial markets in the propagation of cyclical movements. Seminal work reaches back to Fisher (1933) and Keynes (1936). In the last two decades a body of literature moreover highlights the role of financial frictions for explaining the development of key macroeconomic variables [see amongst others Carlstrom and Fuerst (1997), Bernanke, Gertler, and Gilchrist (1999), Goodfriend and McCallum (2007), or Gertler and Kiyotaki (2009)].[5] Additionally, the financial crisis 2007-2009 again sheds light on the importance of implementing financial frictions into macroeconomic models. Empirical studies as for instance Santos and Winton (2008) show that in particular banks and their non-stationary price-cost margins are of great interest for business cycle dynamics. Further empirical support for non-stationary price-cost margins of banks is for instance given by Aliaga-Díaz and Olivero (2010) who highlight the counter-cyclical nature of mark-ups in the banking sector via VAR forecast error-based methodology for US data. Moreover, Olivero (2010) provides further empirical support for OECD data.

In the recent literature, the counter-cyclical nature of mark-ups in loan markets is commonly implemented by assuming an information asymmetry between borrowers and lenders as for instance in the famous financial accelerator model of Bernanke, Gertler, and Gilchrist (1999). In this study, the authors integrate the Bernanke, Gertler, and Gilchrist (1996) approach into a New Keynesian model. Hence, they build up an overlapping generations model where firms need physical capital and labor for production. The acquisition of capital is financed either by borrowing or by entrepreneurial net wealth. Competitive financial intermediaries ask for an external finance premium (or: mark-up) over their marginal costs for financing capital. This

[5] See Arend (2010) for an insightful overview of newer contributions. See moreover Gertler (1988) for an excellent overview of "traditional" approaches incorporating financial frictions.

mark-up is not caused by an imperfectly competitive environment of financial institutions but by the assumption of information asymmetries across borrowers and lenders. Bernanke, Gertler, and Gilchrist (1999) moreover assume that the external finance premium inversely depends on borrowers' net wealth. Therefore, an enhancement in wealth of borrowers in boom phases leads to a decline in mark-ups in the loan market. This in turn increases the net wealth of borrowers and consequently introduces an amplification effect, the famous *financial accelerator*.

In Chapter 2 and in contrast to that, we do *not* emphasize mark-up movements from the demand side of credits.[6] Instead, our *new* financial accelerator nests from the supply side of credits. More precisely, we extend the baseline New Keynesian model by assuming that firms have to pre-finance their wage-bill. Banks provide loans under oligopolistic competition using deposits and money market credits.[7] Moreover, the number of oligopolistic banks is non-stationary and endogenously determined. This combination enables us to draw the endogenous causality that an increasing number of banks causes the market share of the single financial intermediary and thus the resulting mark-up to decline. In Chapter 2, we show that the latter relation in turn finds support in the data. We moreover show that bank mark-ups are negatively correlated with the number of banks and that the number of banks in turn co-moves with GDP in the US economy.

The analysis of the resulting impulse responses shows that our framework can indeed depict both the empirically observed pro-cyclical nature of the number of banks as well as the counter-cyclical nature of mark-up movements. Thereby, the endogenous mark-up movements resulting from oligopolistic competition generate large amplification and persistence effects. In particular, we obtain significantly higher accelerating effects than those generated by the famous financial accelerator model of Bernanke, Gertler, and Gilchrist (1999). Notably, we obtain the largest accelerating effect in the case of a shock to the nominal interest rate.

Our financial accelerator works as follows. Due to increasing profit opportunities for banks in economic upturns, the number of banks increases in response to expansionary shocks. The market share of the single bank consequently decreases. As a result, banks have to decrease their mark-ups. Since firms have to pre-finance their wage-bill, a decreasing bank mark-up has in turn a positive effect on the marginal costs of firms leading to a further increase in production and thus in loan demand. Consequently, the endogenous mark-up movements resulting from oligopolistic competition[8] induces a multiplier (or: amplification) effect, the *new* financial accelerator.

[6] In the following, we will use the expressions "credit" and "loan" synonymously.

[7] Following amongst others Henzel et al. (2009) and Hülsewig, Meyer, and Wollmershäuser (2009), we assume deposits and money market credits to be perfect substitutes. Consequently, the deposit rate and the money market rate – the instrument of the central bank – have to coincide [see also Freixas and Rochet (1997)].

[8] Remark: In the case of *monopolistic* competition, the mark-up of a competitor tends to zero. As a result, the mark-ups are constant in such an environment.

As the famous financial accelerator model of Bernanke, Gertler, and Gilchrist (1999), our framework thus represents a further step to solve the puzzle how relatively small shocks can result in large and persistent effects for the real economy [see amongst others Mankiw (2001), Chari, Kehoe, and McGrattan (2000), Bernanke, Gertler, and Gilchrist (1999), and Fuhrer and Moore (1995)].

Thereby, our framework provides a *new transmission channel* for monetary policy via bank creation which works as follows. A contractionary shock to the instrument of the central bank, the nominal interest rate, results in four expansionary effects. (i) Consumption is shifted into the present leading to a higher loan demand. (ii) The marginal costs of banks decrease. (iii) Bank entry costs decline, too.[9] (iv) The value of a bank which is defined as the discounted sum of future profits increases due to the lower discount rate. The first two effects result in higher bank profits while the latter two effects have moreover an expansionary impact on the profitability of bank start-ups which result in an increase in investment in new banks. All in all, the resulting expansionary reaction of the number of operating banks leads to a lower market share of a single bank. Hence, the declining mark-up on the loan market introduces the *new* financial accelerator.[10]

As standard in the macroeconomics literature, we finally evaluate our model by comparing the second moments[11] of the generated series with those observed in US data. The analysis shows that the model performs remarkable well with respect to this dimension. In particular, it does not only depict the properties of key macroeconomic variables appropriately but also those of financial variables. Moreover, we analyze the macroeconomic implications of a financial activity tax and a financial transaction tax. Our analysis points out that these two taxes are indeed an appropriate tool to stabilize financial markets[12] and thus to dampen the volatility of key macroeconomic variables. We find that the financial activity tax where banks have to pay a tax on each transaction is significantly more effective in extenuating macroeconomic volatility than the financial transaction tax where the tax base is simply per period profits.[13]

[9] Remark: We assume that deposits are needed to build up new banks.

[10] By contrast, the transmission channel for monetary policy in Bernanke, Gertler, and Gilchrist (1999) works as follows. An easing of monetary policy increases the return on capital resulting in an increase in the net wealth of firms. This in turn causes a decrease in firm leverage leading to a reduction of the external finance premium and thus to a further rise in capital demand. This in turn leads to an additional expansionary effect for the production sector.

[11] These evaluations typically include an analysis of the generated variances – in absolute and relative terms – autocorrelations, and/or cross-correlations.

[12] This result is in line with the findings of the partial analyses of Tobin (1978) taxes in amongst others Dieci and Westerhoff (2004).

[13] This result is also obtained by Lengnick and Wohltmann (2010) who extend a simplified framework à la Bernanke, Gertler, and Gilchrist (1999) by a high-frequency asset market as in Dieci and Westerhoff (2004).

The Extensive Margin of Production

In the baseline New Keynesian framework, the mass of firms is assumed to be constant over time. However, there is empirical support that the number of producing firms varies over time and significantly co-moves with GDP [see amongst others Devereux, Head, and Lapham (1996) or Bergin and Corsetti (2008)]. In line with this finding, there already exists a small but growing strand of literature dealing with endogenous firm entry initiated by the trade models of Ghironi and Melitz (2005) and Melitz (2003). Bilbiie, Ghironi, and Melitz (2007a) and Bilbiie, Ghironi, and Melitz (2007b) respectively extend this framework to an RBC and a New Keynesian model. These studies have become the workhorse models for analyzing the macroeconomic effects resulting from an endogenous mass of firms. For the sake of simplicity, the authors however assume that firms are homogeneous and that only firm entry is endogenously determined. By contrast, the death rate of firms is constant over time. More precisely, they assume that with a given (constant) probability firms are hit with a death shock at the very end of each period. However, the empirical study of Campbell (1998) shows that, although the entry rate of new firms is significantly correlated with GDP, the co-movement between the business cycle and firms' failures is even larger. In Chapter 3, we present a similar finding. This result is moreover confirmed by Jaimovich and Floetotto (2008) who find negative and highly significant correlations between GDP and firms' failures based on industry level data. Therefore, the aim of Chapter 3 is to contribute to the literature by providing a New Keynesian model with an alternative mechanism which allows for *simultaneous* endogenous firm entry and exit.

More precisely, we develop an approach which only differs from the baseline New Keynesian model presented in Section 1.1 via the production sector. We assume the firms to be heterogeneous with respect to their individual productivity. They thus produce with different technologies.[14] Moreover, we do no longer stick to the assumption of a constant mass of firms. In particular, both the entry and exit decisions of firms are based on present value criteria. More precisely, if on the one hand an existing firm expects a non-positive net present value of current and future production, it will consequently leave the market.[15] On the other hand, a new firm will enter, if its entry is profitable, i.e. if the present value of production exceeds the entry costs. Of course, the entry and exit decisions crucially depend on the respective individual productivity level in our model. This implies that good (i.e. productive) firms will thus stay in the market or will enter it, while bad firms will leave. Beside that the derived model is standard.

Our framework has several advantages when compared to the workhorse model of

[14] We assume that the individual productivity levels are Pareto distributed which captures industry level data quite well [cf. Ghironi and Melitz (2005).]

[15] Remark: The present value of production is defined as the discounted sum of all current and future profits. The *net* present value is then defined as the present value of production minus entering/exiting costs.

Bilbiie, Ghironi, and Melitz (2007a,b). Especially in the case of monetary and fiscal interventions our model is more conclusive in some important economic aspects. More precisely, the model of Bilbiie, Ghironi, and Melitz (2007b) generates a *decrease* in the mass of producers in the case of an expansionary shock to monetary policy. This however conflicts with the empirical insights of Bergin and Corsetti (2008). Their VAR analysis shows that a decrease in the interest rate *encourages* firm entry. In line with this finding, our framework generates the suggested *increase* in the mass of products[16] even in a simplified specification of the model where exits are assumed to be exogenous. The economic rationale is that due to *heterogeneity* – also across potential firms – there will always exists a firm with an individual productivity level that is only *slightly* too low for a profitable entry.[17] As a consequence, also small expansionary shocks can result in an increase in the mass of firms. When assuming homogeneity across firms as in Bilbiie, Ghironi, and Melitz (2007a,b), this does *not* have to hold.

A further problem of the models of Bilbiie, Ghironi, and Melitz (2007a,b) is that they do *not* perform better than standard RBC models with respect to the generated second moments [see Bilbiie, Ghironi, and Melitz (2007a,b)]. By contrast, our model performs better since it solves two problems of standard New Keynesian and RBC models. First, in our approach total hours worked and consumption do *not* react *too smooth* relative to output.[18] Second, all variables do *not* behave *too pro-cyclical*.[19] When assuming firm exits to be exogenous the results become worse. Hence, an endogenous tendency of firms to leave the market should not be neglected.

In addition, our model can contribute to the debate in the RBC literature initiated by Galí (1999), whether an overall productivity shock leads to an expansionary or a contractionary reaction of total hours worked. In the empirical literature, there is a widespread agreement that there exists a *negative* correlation between total hours worked and GDP [see amongst others Francis and Ramey (2004, 2005), Galí and Rabanal (2004), and Galí (1999)]. However, standard RBC models generate a *positive* co-movement.[20] By making prices totally flexible and considering capital, the resulting RBC core of our model can depict both possibilities when the intertemporal elasticity of substitution is varied within an empirically plausible range. The

[16]Remark: As standard in the macroeconomics literature, there is a one-to-one identification between a firm and a product. We will thus use the latter expressions synonymously.

[17]Note that this result would also hold for other distributions of the individual productivity level, e.g. a Normal or Student's t-distribution.

[18]This implies that the generated standard deviations of total hours worked and consumption in our framework are not too small in relation to the standard deviation of GDP as in standard RBC and New Keynesian models [cf. King and Rebelo (1999)].

[19]This implies that the generated autocorrelations in our model are not too large when compared to the empirically observed ones as in standard RBC and New Keynesian models [cf. King and Rebelo (1999)].

[20]Remark: Within a classical monetary model, i.e. an RBC framework without capital in production, the sign of the reaction of hours worked crucially depends on the intertemporal elasticity of substitution [cf. Galí (2008, Ch.2)]. However, when considering capital in the model, hours worked always react expansionary [cf. Galí (1999)].

underlying driving force is the development of the mass of producing firms.

As producer price index (PPI) inflation and consumer price index (CPI) inflation do not coincide in general in our approach, we derive two specifications of the New Keynesian Phillips curve. We show that in our model PPI inflation is only affected by expected future inflation and the labor share as in the baseline Phillips curve. This result moreover finds support in US economy data as there does not exist a significant correlation between PPI inflation and the extensive margin.[21] In the case of CPI inflation, there however exists a variety effect[22] in our theoretical framework since the CPI Phillips curve is also a function of the change in the mass of producers. This result finds support in US economy data, too, since we find that CPI inflation is significantly correlated with the change in the number of producers. We estimate the latter specification of the Phillips curve using the generalized method of moments. We show that the impact of the change in the extensive margin on CPI inflation is highly significant in the reduced form as well as in the structural estimation. In comparison with the baseline New Keynesian Phillips curve, our CPI Phillips curve becomes flatter in an inflation/labor share-space. This implies that the introduction of an endogenous mass of producers causes the impact of the labor share on inflation to decrease as there occur additional effects from changes in the mass of firms.

The Stabilization and Inflation Bias

In the baseline New Keynesian model, the monetary authority follows an instrument rule of Taylor (1993) type. In reality, central banks however do not strictly rely on a commitment strategy. Instead, they deviate from their rules for instance in the presence of large shocks. The topic of policy switching regimes and the resulting consequences for the credibility of central banks are already discussed in the famous studies of Barro and Gordon (1983a,b). However, the authors do not consider any demand side effects of the economy in their approach. Moreover, the authors assume for the sake of simplicity that the central bank can directly control for the inflation rate.

There already exists a couple of studies which show that the crucial assumption made by Barro and Gordon (1983a,b) namely, that the central bank aims at an output gap target larger than zero,[23] leads to an inflation bias in a New Keynesian framework, too [see amongst others Clarida, Galí, and Gertler (1999)]. However, an explicit derivation and the analysis of the resulting welfare consequences of optimal monetary policy, including purely discretionary and inconsistent monetary policy as well as time-(in)consistent Taylor rules, are neglected in the literature. This will be

[21] In the following, we will use the expressions "mass of firms" and "extensive margin" synonymously.

[22] Remark: The variety effect implies that an increase in the mass of firms leads ceteris paribus to an increase in output and the price of goods [see Benassy (1996) or Bergin and Corsetti (2008)].

[23] An economic rationale for this assumption is that for instance monopolistic distortions or taxes keep potential output below its efficient level [cf. Clarida, Galí, and Gertler (1999)].

the aim of Chapter 4.

In particular, Chapter 4 offers an approach which enables us to discuss both the debate in the New Keynesian literature about the optimality of commitment vs. discretion and the time-inconsistency problem à la Barro and Gordon (1983a,b) within a unified framework. By assuming that the central bank aims at an output gap target larger than zero as in Barro and Gordon (1983a,b), we can solve the inconsistency problem and derive time-consistent (or: stable) interest rate rules of Taylor-type within the standard New Keynesian model. Thereby, this framework enables us to consider the demand side of the economy and to deviate from the assumption that the central bank can directly control for the inflation rate. Instead, the mechanism in New Keynesian models is as follows. (i) The central bank commits itself to follow an interest rate rule of Taylor-type. (ii) Private agents form inflation expectations. (iii) The central bank sets the interest rate and the households adjust their consumption expenditures according to the Euler consumption equation. (iv) Inflation is then determined by expected future inflation and the output realization via the New Keynesian Phillips curve.

Our main findings are as follows. Under a completely standard calibration including a time preference rate of the monetary authority equal to the long-run interest rate, the standard Taylor rule is time-consistent (or: stable) in the presence of a cost-push shock. The central bank thus does not have an incentive to deviate from the announced rule and to switch over to the inconsistent policy regime. However, there exists a multiplicity of stable Taylor rules which are superior to the standard one. In contrast to the Kydland/Prescott-Barro/Gordon approach, implementing a monetary rule such that the cost and benefit resulting from inconsistent policy coincide – which implies a net gain of inconsistent policy behavior equal to zero – is *not* optimal. Instead, the solution can be enhanced by moving *into* the time-consistent area where the net gain of inconsistent monetary policy is negative. Moreover, there does not exist a stable monetary policy rule maximizing the welfare when considering monetary policy of Taylor-type rules. The continuum of stable rules furthermore becomes larger when assuming an additional term in the social loss function concerning interest rate stability. This implies that the reputation of the central bank naturally improves if the policy maker is also concerned about stabilizing the interest rate. Our results remain robust with respect to the analysis of simultaneous supply and demand shocks.

A New Dimension for Evaluating Fiscal Policy

In order to fight the recessionary impacts of the recent financial crisis, governments throughout the globe have passed large fiscal packages and thereby triggered a debate about the effectiveness of government spending in stimulating economic activity.

In this context, Cogan et al. (2010) employ an empirically estimated New Keynesian model for the US economy[24] [Smets and Wouters (2007)] also incorporating rule-of-thumb consumers and report a multiplier *less than one*.[25] Faia, Lechthaler, and Merkl (2010b) and Campolmi, Faia, and Winkler (2010) demonstrate that a pure demand stimulus leads to very small (or even negative) multipliers in models with frictional labor markets. Moreover, both studies emphasize that other forms of fiscal stimuli such as hiring subsidies or income tax cuts are much more effective in boosting output and employment. The implications of a fiscal demand shock in the baseline New Keynesian model are investigated in Linnemann and Schabert (2003).

All these contributions analyze the impacts of fiscal stimuli on standard measures of economic activity (GDP, employment, investment) but *neglect* their impact on the extensive margin, i.e. the mass of existing firms in the economy. However, a recent literature highlights the role of an endogenous mass of firms as an important propagation and amplification mechanism for business cycle fluctuations [see amongst others Devereux, Head, and Lapham (1996) and Bergin and Corsetti (2008)]. Bilbiie, Ghironi, and Melitz (2007a) and Bergin and Corsetti (2008) respectively demonstrate that technological innovations and shocks to monetary policy are amplified by endogenizing the extensive margin. With respect to fiscal interventions, a substantial pro-cyclical behavior of the mass of firms may help to explain how fiscal stimuli generate large and persistent business cycle fluctuations. In particular, this amplification effect potentially gives rise to *larger* fiscal multipliers.[26]

The aim of Chapter 5 is thus twofold. First, we explore the impacts of *different* fiscal stimuli on firm entry applying a variant of the workhorse firm entry model of Bilbiie, Ghironi, and Melitz (2007a) with capital in production which we estimate for the US using Bayesian techniques.[27] Second, we calculate fiscal multipliers for both the model with an endogenous mass of firms and the standard RBC model with a constant mass of firms. This enables us to investigate whether a changing mass of firms alters the effectiveness of fiscal stimuli. Moreover, our framework allows for a closer examination of investment decisions – and correspondingly crowding-out/in effects of fiscal interventions – since we can distinguish between investments in physical capital and those in new products. Beside an increase in government spending[28] financed by lump-sum taxation, we moreover consider *other* forms of

[24] Cwik and Wieland (2009) report a similar finding for the Euro area.

[25] Note that this finding is equivalent to the well-known Haavelmo (1945) theorem. It implies that for instance in the IS/LM framework, an increase in fiscal expenditure financed by taxes leads to a multiplier less than one and to a reduction of private consumption [see also Wohltmann (2007)].

[26] Other well-known mechanisms to generate larger fiscal multipliers are for instance the introduction of sticky prices [cf. Linnemann and Schabert (2003)], rule-of-thumb consumers [cf. Galí, López-Salido, and Vallès (2007)] or backward indexation of prices [cf. Chari, Kehoe, and McGrattan (2009)]. We however want to analyze the *pure* effects of firm entry on fiscal multipliers.

[27] In contrast to Faia, Lechthaler, and Merkl (2010b) and Campolmi, Faia, and Winkler (2010), we follow Bilbiie, Ghironi, and Melitz (2007a,b) by assuming labor markets to be complete as in the baseline New Keynesian and RBC model.

[28] As standard in the literature, we assume that the government only purchases consumption goods [see amongst

fiscal stimuli. More precisely, we analyze the effects in response to cuts in the labor income tax, the capital income tax, the dividend income tax, and the consumption tax. Note however that the aim of Chapter 5 is *not* to provide a thorough quantitative evaluation of fiscal packages since we do not apply a large scale DSGE model with several nominal and real frictions as for instance in Cogan et al. (2010) or Cwik and Wieland (2009). Instead, we apply a rather simple framework to focus on the qualitative and quantitative differences to the standard RBC model resulting from endogenous firm entry.

Our main findings are as follows. We demonstrate that the extensive margin *can* indeed act as an accelerator for the impacts of fiscal stimuli. However, we find that the qualitative reaction of the mass of firms – in particular, the sign of the corresponding reaction – crucially depends on the form of a fiscal stimulus. Moreover, we find that if in response to a fiscal intervention the mass of firms *increases*, fiscal multipliers[29] – in the long-run and in the short-run – are *amplified*. In this case, two expansionary effects arise. First, an increasing extensive margin has a positive impact on goods production via the 'love of variety effect' [see Benassy (1996) and Bergin and Corsetti (2008)]. This effect directly follows from the aggregation of intermediate goods and implies that an increase in the mass of firms has ceteris paribus a positive impact on aggregate production. Second, households have to invest in start-ups to create new firms. Additional investments in turn boost GDP.[30] When compared to the baseline model – with a constant extensive margin – the multipliers are significantly larger. If, by contrast, the mass of firms *decreases* in response to a fiscal intervention,[31] the extensive margin *dampens* the impacts of fiscal stimuli on economic activity. The drop in new firm investment then results in an additional crowding-out effect. In comparison with the standard RBC model, the resulting multipliers are then significantly smaller.

Our impulse response analysis based on the *estimated* mean of the parameters shows that investment in new firms decreases in response to an increase in government consumption. This additional crowding-out effect pushes the multiplier *below* that

others Smets and Wouters (2007, 2003), Galí, López-Salido, and Vallès (2007) or Linnemann and Schabert (2003)]. Therefore, we will use the expressions "government spending" and "government consumption" synonymously. Alternatively, Leeper, Walker, and Yang (2010) consider government investment or Cavallo (2005), Gomes (2009) or Leeper, Walker, and Yang (2010) assume that governments employ workers to produce goods used for government consumption or government investment. However, these approaches do not generate larger multiplier. Instead, they often generate negative short-run multipliers before they turn positive in the longer-run.

[29] We calculate the dynamic fiscal multiplier as proposed by Uhlig (2010). Moreover, we define the short-run multiplier as the discounted change in GDP in the first year divided by the discounted costs of a fiscal stimulus during the first year. The long-run multiplier is defined as the discounted overall changes in output divided by the discounted overall costs.

[30] The latter effect is analogous to our financial accelerator model of Chapter 2 since in both models GDP includes investment in new start-ups.

[31] In particular, this is the case in response to a temporary drop in the capital tax since we find a substitution relation between investment in new firms and investment in physical capital. The mass of firms also decreases in response to an increase in government spending financed not only by lump-sum but distortionary taxes.

of the benchmark model with a constant mass of firms. A similar result is found for the case of a demand stimulus through a cut in consumption taxes. However, we show that the reaction of the extensive margin in response to an increase in government consumption or a cut in consumption taxes turns out to be *ambiguous*. In line with this finding, Lewis (2009b) points out that the mass of firms only reacts expansionary if the fiscal demand shock is sufficiently persistent. The economic rationale is that only under highly persistent shocks potential firms expect future profit opportunities which cover the entry cost and consequently enter the market.

We extend this analysis by demonstrating that the ambiguous impact of government consumption shocks on the mass of firms is *not only* driven by the shock persistence in isolation but by the combination of the latter with the labor supply elasticity. The economic intuition why the reaction of the mass of product varieties may turn negative when the labor supply elasticity is low is as follows. Suppose labor is the only input in production and is supplied totally inelastic. In an RBC model with a fixed mass of producers, an increase in government consumption consequently causes a complete crowding-out of private consumption. In the entry model, however, households can reallocate their labor force between working in the manufacturing sector and creating new products.[32] Households are then able to dampen the drop in private consumption by increasing hours worked in the manufacturing sector and decreasing hours worked for product creation. The mass of firms consequently declines when labor supply is sufficiently inelastic. Furthermore, we show that the source of government financing such as distortionary income taxes is a crucial dimension, too.

Due to the fact that fiscal demand stimuli may cause a crowding-out not only of investment in physical capital and consumption but also of investment in new firms, we show that these interventions lead to *small* fiscal multipliers in the applied framework.[33] By contrast, the multipliers of labor and dividend tax cuts are *significantly larger*.[34] The reason is that in these cases we find a crowding-in of private consump-

[32] Bilbiie, Ghironi, and Melitz (2007a,b) assume that labor is needed to create new firms.

[33] Note that we apply an RBC framework. A corresponding "traditional" approach would be the famous AD/AS-model with flexible prices and wages of a closed economy [neoclassical variant, see amongst others Wohltmann (2007, Ch. 6)]. In this framework, an increase in government spending has no effects on output, at all, since it does not affect the supply side of production. By contrast, an increase in government spending financed by lump-sum taxation leads to an increase in labor supply in an RBC framework caused by the negative *wealth effect* [cf. Baxter and King (1993)]. The wealth effect works as follows. Since the increase in government spending is financed by lump-sum taxation, it represents a negative effect on the total income of households. The households consequently decrease their consumption expenditures and increase their labor supply to compensate for the additional tax expenditures. This increase in labor supply in turn leads to an expansionary reaction of production. In contrast to traditional approaches, this wealth effect is thus *not* a direct but an indirect effect.

[34] This is not a very surprising result since these taxes are distortionary and have a direct impact on the supply side of the economy. Moreover, the cuts in these tax rates are financed by lump-sum taxation which additionally lead to an expansionary reaction of production via the negative wealth effect. The result that tax cuts which affect the supply of production lead to larger multipliers than an increase in government spending is already known from the neoclassical variant of the AD/AS-model, too. This is for instance the case when analyzing a cut in ancillary labor costs. This tax cut has positive effects on GDP while – as already mentioned – an increase in government spending has no effects in such an environment [cf. Wohltmann (2007, Ch. 6)].

tion, of investment in existing capital, and of investment in product creation. The latter effect in turn leads to an increasing mass of firms. Although the multiplier of a cut in capital taxes is also close to one, this policy comes at the cost of a crowding-out in new firm investment and thus of a decrease in the mass of firms.

Moreover, we contribute to the literature by conducting a Bayesian estimation of a DSGE model with firm entry incorporating *several* structural shocks. In a complementary study, Lewis and Poilly (2010) estimate a DSGE model with firm entry by using a VAR minimum distance approach. They apply a framework with several nominal and real frictions but focus on a *single* shock to monetary policy.

Part One: Extensions of the baseline New Keynesian Model

2 Banks, Oligopolistic Competition, and the Business Cycle: A New Financial Accelerator Approach

2.1 Introduction

As Gertler (1988) states, there already exists a long-standing tradition in macroeconomic theory that emphasizes a central role to financial markets in the propagation of cyclical movements. Seminal work reaches back to Fisher (1933) and Keynes (1936). In the last two decades a body of literature moreover highlights the role of financial frictions for explaining the development of key macroeconomic variables [see amongst others Carlstrom and Fuerst (1997), Bernanke, Gertler, and Gilchrist (1999), Goodfriend and McCallum (2007), or Gertler and Kiyotaki (2009)].[1] Additionally, the financial crisis 2007-2009 again sheds light on the importance of implementing financial frictions into macro models. In this chapter,[2] we contribute to the literature by simultaneously explaining two empirical observations. First, mark-ups on the loan market react counter-cyclical. Second, the number of banks operating in the economy significantly co-moves with GDP.

Figure 2.1 depicts these observations for US data including the corresponding cross-correlations. As a measure for the mark-up of a commercial bank we choose the spread between the average majority prime rate charged by banks on short-term loans to business and the FED's funds rate.[3] The data is logged and de-trended by application of the Hodrick-Prescott filter. Figure 2.1 shows that the number of banks significantly co-moves with GDP. The corresponding cross-correlation is 0.49. Moreover, bank mark-ups react counter-cyclical. The corresponding cross-correlation is -0.88. Further empirical support for non-stationary price-cost margins of banks is for instance given by Aliaga-Díaz and Olivero (2010) who highlight the counter-cyclical nature of mark-ups in the banking sector via VAR forecast error-based methodology for US data [see also Santos and Winton (2008)]. Moreover, Olivero (2010) provides further empirical support for OECD data.

[1] See Arend (2010) for an insightful overview of newer contributions. See moreover Gertler (1988) for an excellent overview of "traditional" approaches incorporating financial frictions.

[2] For a different version of this chapter see "Banks, Oligopolistic Competition, and the Business Cycle: A New Financial Accelerator Approach", Economics Working Paper 2011-02, Department of Economics, Christian-Albrechts-Universität zu Kiel.

[3] The data for the loan rate and the number of banks is provided by http://www.federalreserve.gov.

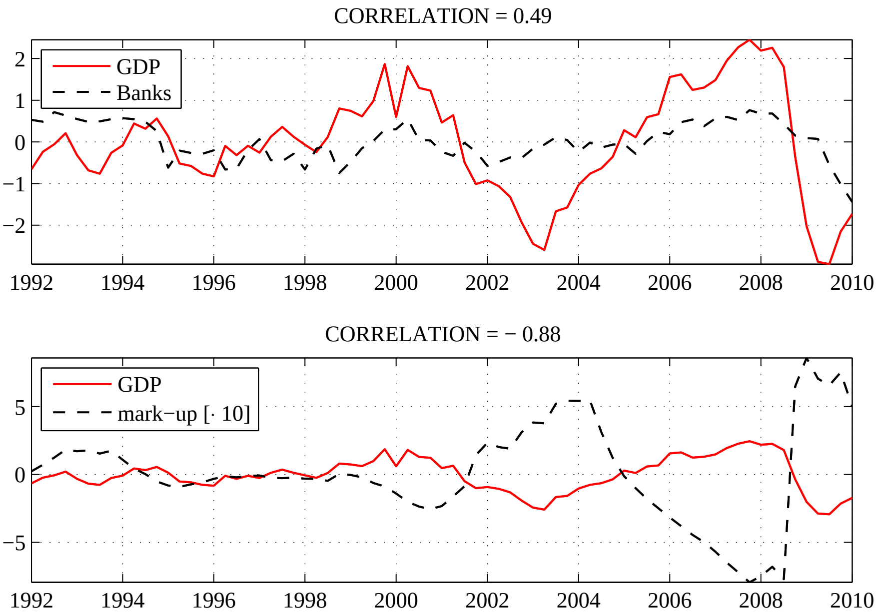

Figure 2.1: *On the counter-cyclical nature of the number of banks and banks' mark-up [US data in logs and HP-filtered]*

In the recent literature, the counter-cyclical nature of mark-ups in loan markets is commonly implemented by assuming an information asymmetry between borrowers and lenders as for instance in the famous financial accelerator model of Bernanke, Gertler, and Gilchrist (1999). In this study, the authors integrate the Bernanke, Gertler, and Gilchrist (1996) approach into a New Keynesian model. Hence, they build up an overlapping generations model where firms need physical capital and labor for production. The acquisition of capital is financed either by borrowing or by entrepreneurial net wealth. Competitive financial intermediaries ask for an external finance premium (or: mark-up) over their marginal costs for financing capital. This mark-up is not caused by an imperfectly competitive environment of financial institutions but by the assumption of information asymmetries across borrowers and lenders. Bernanke, Gertler, and Gilchrist (1999) moreover assume that the external finance premium inversely depends on borrowers net wealth. Therefore, an enhancement in wealth of borrowers in boom phases leads to a decline in mark-ups in the loan market. This in turn increases the net wealth of borrowers and consequently introduces an amplification effect, the famous *financial accelerator*.

By contrast, we do *not* emphasize mark-up movements from the demand side of credits.[4] Instead, our *new* financial accelerator nests from the supply side of credits. More precisely, we develop a New Keynesian model which incorporates an oligopolis-

[4]In the following, we will use the expressions "credit" and "loan" synonymously.

tic banking sector with endogenous bank entry. This combination enables us to draw the endogenous causality that an increasing mass of banks causes the market share of the single bank and thus the resulting mark-up to decline. As Figure 2.2 depicts that the latter relation in turn finds support in the data since we found a significant negative correlation (-0.43) between bank mark-ups and the number of operating banks, too.

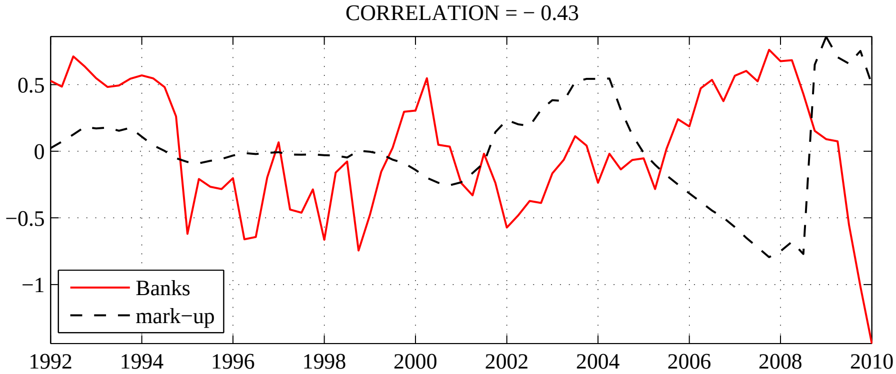

Figure 2.2: *The number of banks and their mark-ups*

We follow Christiano, Eichenbaum, and Evans (2005) by assuming that firms have to pre-finance their wage-bill. Therefore, banks provide loans under oligopolistic competition using deposits and money market credits. Thereby, our model generates a financial accelerator which works as follows. Due to increasing profit opportunities for banks in economic upturns, the mass of banks increases in response to expansionary shocks. The market share of the single bank consequently decreases. As a result, banks have to decrease their mark-ups. Since firms have to pre-finance their wage-bill, a decreasing bank mark-up has in turn a positive effect on the marginal costs of firms leading to a further increase in production and thus in loan demand. Consequently, the endogenous mark-up movements resulting from oligopolistic competition[5] induces a multiplier (or: amplification) effect, the *new* financial accelerator.

Thereby, our framework provides a new transmission channel for monetary policy via bank creation which works as follows. A contractionary shock to the instrument of the central bank, the nominal interest rate, results in four expansionary effects. (i) Consumption is shifted into the present leading to a higher loan demand. (ii) The marginal costs of banks decrease. (iii) Bank entry costs decline, too.[6] (iv) The value of a bank which is defined as the discounted sum of future profits increases due to the lower discount rate. The first two effects result in higher bank profits while the latter two effects have moreover an expansionary impact on the profitability of

[5]Remark: In the case of monopolistic competition, the mark-up of a competitor tends to zero. As a result, the mark-ups are constant in such an environment.
[6]Remark: We assume that deposits are needed to build up new banks.

bank start-ups which result in an increase in investment in new banks. All in all, the resulting expansionary reaction of the mass of operating banks leads to a lower market share of a single bank and introduces the new financial accelerator.[7]

The analysis of the resulting impulse responses shows that our framework can indeed depict both the pro-cyclicality of the mass of financial intermediaries as well as the counter-cyclical nature of mark-up movements. Thereby, the resulting endogenous bank entry generates large amplification and persistence effects. In particular, we obtain significantly higher accelerating effects than those generated by the probably most famous study of BGG. It is moreover worth mentioning that in contrast with for instance Meh and Moran (2010) where amplification effects are stronger for supply shocks, we also generate significant amplification effects from demand shocks.[8] Notably, we obtain the largest accelerating effect in the case of a monetary policy shock.

Financial crises have taught us that banks do not only propagate shocks but can also be the source of financial disturbances which have important implications for the real economy. In this context, we investigate the implications of a contractionary shock to bank value. Our analysis shows that the financial shock results in stagflationary effects. The rationale is that the non-stationary bank mark-up acts as an endogenous cost-push shock for the real economy. Note however that the aim of this chapter is not to explain the financial crisis of 2007-2009. Our framework is naturally too simple to depict such a complex event. As the famous financial accelerator model of BGG, our framework, instead, represents a further step to solve the puzzle how relatively small shocks can result in large and persistent effects for the real economy [see amongst other Mankiw (2001), Chari, Kehoe, and McGrattan (2000), and Fuhrer and Moore (1995)].

As standard in macroeconomics literature, we finally evaluate our model by comparing the second moments of the generated series with those observed in US data. The analysis shows that the model performs remarkable well with respect to this dimension. In particular, it does not only depict the properties of key macroeconomic variables appropriately but also those of financial variables including the mass of banks, the amount of aggregate loans, and the amount of loans per banks. Moreover, we analyze the macroeconomic implications of a financial activity tax and a financial transaction tax.[9] Our analysis points out that these two taxes are indeed an

[7] By contrast, the transmission channel for monetary policy in Bernanke, Gertler, and Gilchrist (1999) works as follows. An easing of monetary policy increases the return on capital resulting in an increase in the net wealth of firms. This in turn causes a decrease in firm leverage leading to a reduction of the external finance premium and thus to a further rise in capital demand. This in turn leads to an additional expansionary effect for the production sector.

[8] Meh and Moran (2010) build up a DSGE model in which bank capital mitigates an agency problem between banks and their creditors. In their approach, the resulting propagation effect results from the bank capital channel.

[9] For the partial analysis of Tobin (1978) taxes see amongst others Dieci and Westerhoff (2004). See moreover Lengnick and Wohltmann (2010) who extend a simplified framework à la BGG for a high frequent asset

appropriate tool to stabilize the financial markets and thus to dampen the volatility of key macroeconomic variables. We find that the financial activity tax where banks have to pay a tax on each transaction is significantly more effective than the financial transaction tax where the tax base is simply per period profits. The rationale is that the financial transaction tax does not only affect the profitability of bank start-ups but also affects the marginal costs of banks. By contrast, the financial activity tax has not any impact on the marginal costs of banks.

The remainder is structured as follows. In Section 2.2, we develop the New Keynesian model incorporating an oligopolistic banking sector with endogenous bank entry. Moreover, we present a benchmark model and the calibration. In Section 2.3, we discuss the impulse responses to a shock to total factor productivity under different assumptions concerning the loan rate stickiness and the survival probability of new banks. We moreover present the new transmission mechanism of monetary policy when considering a shock to the interest rate. Furthermore, we analyze the impulse responses to a fiscal demand stimulus and to a contractionary shock to bank value. The evaluation of the bank entry model is presented in Section 2.4 by comparing the generated second moments with the data. The last section concludes.

2.2 The Model

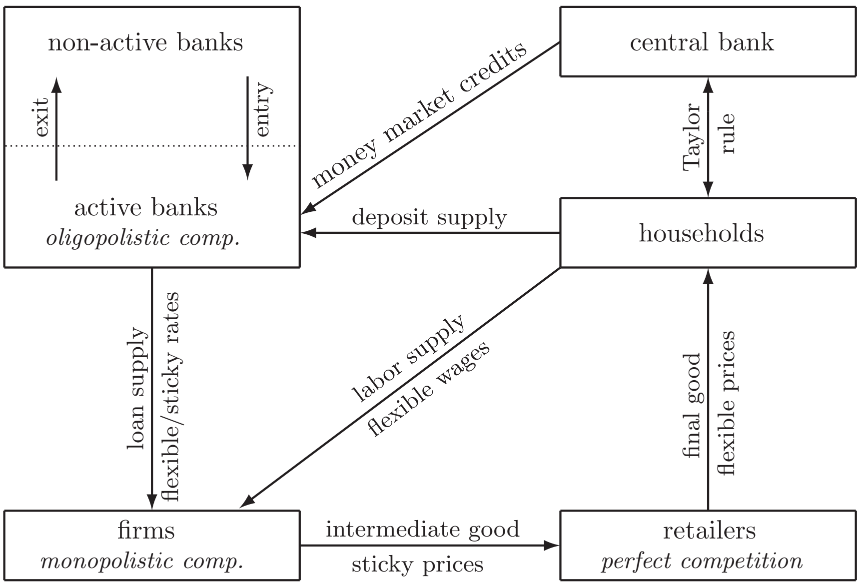

Figure 2.3: *Model structure*

Beside the central bank, the model consists of four types of agents, namely house-

market in the spirit of the latter study. They show that this extension leads to significantly more persistent dynamics.

holds, intermediate good producers (or: firms), retailers, and banks. We assume that firms have to pre-finance their wage bill [see amongst others Christiano, Eichenbaum, and Evans (2005)]. Beside that, firms are totally standard. They produce using labor and sell their differentiated intermediate goods under monopolistic competition to the retailers.

Banks provide loans to firms under oligopolistic competition using deposits and money market credits. Thereby, the mark-up of a single bank endogenously depends on the degree of competition, i.e. on the mass of banks operating in the loan market. Caused by endogenous bank entry and exit, the mass of banks is non-stationary. In our analysis, we will discuss flexible and sticky loan rates.

Households can invest in interest bearing deposits with a duration of one period at a bank. They moreover supply their working force to firms. The retailers bundle the differentiated intermediate goods to a final good and sell it under perfectly competitive conditions to the households. Monetary policy is simply represented by a standard Taylor rule. The complete model structure is depicted in Figure 2.3.

2.2.1 Households

The representative household maximizes its life-time utility value

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\chi}{1+\eta} L_t^{1+\eta} \right) \tag{2.1}$$

subjected to its period-by-period budget constraint

$$\frac{B_t}{P_t} + C_t = w_t L_t + R_{t-1}^B \frac{B_{t-1}}{P_t} + \tau_t \tag{2.2}$$

where $\sigma > 0$ and $\eta > 0$ are the inverse of the intertemporal elasticity of substitution and the Frisch elasticity of labor supply, respectively. $\chi > 0$ is a scaling parameter. $\beta \in (0,1)$ represents the private discount factor. According to (2.2), the household uses its net income for consumption, C_t, and investment in deposits, B_t. L_t is labor supply. τ_t, w_t, R_t^B, and P_t denote transfers, the real wage, the gross nominal deposit rate, and the price index, respectively. E denotes the rational expectations operator.

The household's optimization results in the standard Euler consumption equation and the labor supply equation which are respectively given by

$$C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} \frac{R_t^B}{\pi_{t+1}} \right\} \tag{2.3}$$

$$w_t = \chi C_t^{\sigma} L_t^{\eta} \tag{2.4}$$

where $\pi_t \equiv P_t / P_{t-1}$ is the gross inflation rate.

2.2.2 Retailers

The retailer bundles the intermediate goods, $y_{j,t}$, according to the following CES technology

$$Y_t \equiv \left[\int_0^1 y_{j,t}^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \tag{2.5}$$

where Y_t denotes the final good. θ is the intratemporal elasticity of substitution between intermediate goods.[10]

Equation (2.5) implies the price index, P_t, to follow

$$P_t = \left[\int_0^1 p_{j,t}^{1-\theta} dj\right]^{\frac{1}{1-\theta}} \tag{2.6}$$

where $p_{j,t}$ is the price of the intermediate good j.

Cost minimization delivers the optimal goods demand given by

$$y_{j,t} = \left[\frac{p_{j,t}}{P_t}\right]^{-\theta} Y_t \tag{2.7}$$

2.2.3 Firm Sector

As in Christiano, Eichenbaum, and Evans (2005), we assume that firms have to pre-finance their wage bill [see also Henzel et al. (2009), Hülsewig, Meyer, and Wollmershäuser (2009), and Christiano, Motto, and Rostagno (2010)]. Beside this assumption, firms are totally standard. For production, they need only labor. Firms act under monopolistic competition and sell their differentiated intermediate good to the retailers being faced with a sticky price setting mechanism.

The production function of a firm j is given by

$$y_{j,t} = A_t l_{j,t} \tag{2.8}$$

where $l_{j,t}$ denotes the labor demand of firm j. A_t is a technology shock which follows an AR(1) process: $A_t/A = (A_{t-1}/A)^{\rho^a} \exp\{\varepsilon_t^a\}$ where ε_t^a is white noise.

By cost minimization, we obtain the marginal costs, $mc_{j,t}$, of firm j

$$mc_{j,t} = \frac{R_t^L w_t}{A_t} \tag{2.9}$$

where R_t^L and w_t are the gross nominal loan rate and the real wage, respectively. Equation (2.9) implies symmetry across firms, i.e. $mc_{j,t} = mc_t$, since the right-hand side of (2.9) does not include any firm specific variables depending on j.

[10] Remark: We follow the recent literature by assuming that the mass of firms is normalized to one. This implies that in contrast to the banking sector, the mass of firms is assumed to be constant. See Bilbiie, Ghironi, and Melitz (2007a,b) for a macro model with endogenous firm entry.

We moreover assume firms to be faced with quadratic price adjustment costs in the spirit of Rotemberg (1982). Their pricing decision problem is given by

$$\max_{p_{j,t}} \quad E_0 \sum_{t=0}^{\infty} \Delta_{0,t} \left\{ \frac{p_{j,t}}{P_t} y_{j,t} - mc_{j,t} y_{j,t} - \frac{\kappa^f}{2} \left(\frac{p_{j,t}}{p_{j,t-1}} - 1 \right)^2 Y_t \right\} \tag{2.10}$$

subjected to the optimal goods demand of the retailer given by equation (2.7). $\Delta_{0,t}$ denotes the stochastic real discount factor.[11] κ^f can for instance be interpreted as menu costs. E denotes the rational expectations operator.

The optimization yields a standard Phillips curve[12]

$$\theta - 1 = \theta mc_t - \kappa^f \left[(\pi_t - 1)\pi_t - \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (\pi_{t+1} - 1)\pi_{t+1} \frac{Y_{t+1}}{Y_t} \right\} \right] \tag{2.11}$$

where $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate and the ratio $E_t\Delta_{0,t+1}/\Delta_{0,t} = \beta(E_t C_{t+1}/C_t)^{-\sigma}$ follows from the Euler consumption equation (2.3).

As will be shown later, the aggregate loan rate – which is a component of the marginal costs according to (2.9) – is a function of the central bank's instrument, the money market rate. As a result, the combination of (2.9) and (2.11) indicates that the assumption that firms have to pre-finance their wage bill results in a cost channel. There is empirical support that the direct cost effects of short-run nominal interest rates significantly contribute to inflation dynamics. In particular, Chowdhury, Hoffmann, and Schabert (2006) and Ravenna and Walsh (2006) respectively show the existence of a significant impact of the interest rate on the marginal costs via Phillips curve GMM estimations for the majority of the G7 countries and the US economy. Other studies as for instance Henzel et al. (2009), Hülsewig, Meyer, and Wollmershäuser (2009), and Christiano, Eichenbaum, and Evans (2005) also support the existence of a cost channel by methods of indirect inference for the Euro Area and the US economy. In addition Barth and Ramey (2001) show that based on industry level data the interest rate has a significant effect on the marginal costs of firms.[13]

[11] The stochastic discount factor is defined as $\Delta_{0,t} \equiv \beta^t U_{C,t}/U_{C,0}$ where $U_{C,t} = C_t^{-\sigma}$ denotes the derivative of the household's utility function with respect to consumption at time t. According to the Euler consumption equation (2.3), the stochastic discount factor can also be written as a product of short term real interest rates

$$\Delta_{0,t} = \beta^t \frac{U_{C,t}}{U_{C,0}} = \underbrace{\beta \frac{U_{C,1}}{U_{C,0}}}_{(\widetilde{R}_0^B)^{-1}} \cdot \underbrace{\beta \frac{U_{C,2}}{U_{C,1}}}_{(\widetilde{R}_1^B)^{-1}} \cdot \ldots \cdot \underbrace{\beta \frac{U_{C,t}}{U_{C,t-1}}}_{(\widetilde{R}_{t-1}^B)^{-1}} = \Pi_{i=0}^{t-1} (\widetilde{R}_i^B)^{-1}$$

where $\widetilde{R}_t^B \equiv R_t^B P_t / E_t P_{t+1}$ is the gross one-period real interest rate.

[12] Log-linearizing equation (2.11), results in the familiar expression: $\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \widetilde{\kappa} \widehat{mc}_t$ where $\widetilde{\kappa} \equiv (\theta - 1)/\kappa^f$. The hat indicates the log-deviation from the corresponding steady state.

[13] Remark: The empirical evidence that the cost channel does not seem to be present is restricted to the Bayesian estimation of Rabanal (2007) for US data.

2.2.4 Banking Sector

Banks – indexed with i – supply loans to firms under oligopolistic competition using deposits and money market credits.[14]

The real loans, O_t, are aggregated by the following Dixit-Stiglitz aggregator

$$O_t \equiv \left[\int_0^{N_t} o_{i,t}^{\frac{\zeta-1}{\zeta}} \, di \right]^{\frac{\zeta}{\zeta-1}} \tag{2.12}$$

where $o_{i,t}$ denotes the real loan supply of bank i and $\zeta > 1$ is the intratemporal elasticity between loans. $N_t > 1$ is the non-stationary mass of banks operating in the economy.

Equation (2.12) implies an aggregate gross loan rate given by

$$R_t^L = \left[\int_0^{N_t} \left(r_{i,t}^L \right)^{1-\zeta} \, di \right]^{\frac{1}{1-\zeta}} \tag{2.13}$$

where $r_{i,t}^L$ represents the gross loan rate set by bank i.

In a first step, we assume the loan rate to be flexible. Per period profit of a bank i is then given by

$$d_{i,t} = r_{i,t}^L o_{i,t} - R_t^B b_{i,t} - R_t^M m_{i,t} \tag{2.14}$$

where $m_{i,t}$ is the net position on the money market. R_t^M is the gross money market rate which represents the central bank's tool for monetary policy interventions. $b_{i,t}$ is the real amount of deposits used for loan supply by bank i and R_t^B represents the corresponding nominal gross deposit rate. Following Henzel et al. (2009) and Hülsewig, Meyer, and Wollmershäuser (2009), we assume deposits and money market credits to be perfect substitutes. Consequently, the corresponding rates have to coincide, $R_t^M = R_t^B$ [see also Freixas and Rochet (1997)]. This assumption implies that banks act under oligopolistic competition on the loan market while they price deposits competitively. A similar assumption can also be found in amongst others Henzel et al. (2009) and Hülsewig, Meyer, and Wollmershäuser (2009) and finds support in the empirical literature since there exists a vast body of studies providing evidence for market power in the loan market [see amongst others Matthews, Murinde, and Zhao (2007), Claessens and Laeven (2004), DeBandt and Davis (2000), and Molyneux, Lloyd-Williams, and Thornton (1994)]. By contrast and as already pointed out by Olivero (2010), the empirical evidence for the deposit side is very restricted.

The bank maximizes its profit (2.14) subjected to the loan demand function:

$$o_{i,t} = \left[\frac{r_{i,t}^L}{R_t^L} \right]^{-\zeta} O_t \tag{2.15}$$

[14] See Henzel et al. (2009) or Hülsewig, Meyer, and Wollmershäuser (2009) for a corresponding approach with monopolistic competition and a constant mass of banks.

which results from (2.12) and (2.13). Moreover, the bank is faced with the balance sheet constraint:

$$b_{i,t} + m_{i,t} \geq o_{i,t} \tag{2.16}$$

implying that the amount of loans is restricted by the amount of deposits and money market credits.[15] In the optimum equation (2.16) holds with equality.[16] Inserting this expression and $R_t^M = R_t^B$ in (2.14) yields

$$d_{i,t} = r_{i,t}^L o_{i,t} - R_t^B o_{i,t} \tag{2.17}$$

Maximizing profits (2.17) subjected to (2.15) with respect to $r_{i,t}^L$ yields

$$\frac{\partial d_{i,t}}{\partial r_{i,t}^L} = o_{i,t} + r_{i,t}^L \frac{\partial o_{i,t}}{\partial r_{i,t}^L} - R_t^B \frac{\partial o_{i,t}}{\partial r_{i,t}^L} = 0 \tag{2.18}$$

where

$$\frac{\partial o_{i,t}}{\partial r_{i,t}^L} = -\zeta \frac{(r_{i,t}^L)^{-\zeta-1}}{(R_t^L)^{-\zeta}} O_t + \zeta \frac{(r_{i,t}^L)^{-\zeta}}{(R_t^L)^{-\zeta+1}} O_t \frac{\partial R_t^L}{\partial r_{i,t}^L} \tag{2.19}$$

In contrast to the case of monopolistic competition, the individual loan rate, $r_{i,t}^L$, has in turn a direct impact on the aggregate loan rate, R_t^L, and thus on loan demand under oligopolistic competition:[17]

$$\frac{\partial R_t^L}{\partial r_t^l} = \left(\frac{r_{i,t}^L}{R_t^L} \right)^{-\zeta} = \frac{o_{i,t}}{O_t} \tag{2.20}$$

Inserting this expression in (2.19) yields

$$\frac{\partial o_{i,t}}{\partial r_{i,t}^L} = \zeta \frac{o_{i,t}}{r_{i,t}^L} \left(\lambda_{i,t} - 1 \right) \tag{2.21}$$

where we define the market share, $\lambda_{i,t}$, as

$$\lambda_{i,t} \equiv \frac{r_{i,t}^L o_{i,t}}{R_t^L O_t} \tag{2.22}$$

Inserting (2.21) in (2.18) yields

$$r_{i,t}^L = \frac{(1-\lambda_{i,t})\zeta}{(1-\lambda_{i,t})\zeta - 1} R_t^B = \mu_{i,t} R_t^B \tag{2.23}$$

---

[15] In order to keep the model simple, we abstract from an interbanking market. See for instance Goodfriend and McCallum (2007) for a New Keynesian model incorporating a banking sector with interbank lending.

[16] We abstract from risky credits. As a result, banks do not hold reserves.

[17] Remark: Monopolistic competition was introduced by Chamberlin (1933). The point of monopolistic competition is *not* to study strategic aspects between competitors such as price competition but to abstract from these issues to *simplify* the analysis [see also Blanchard and Kiyotaki (1987)]. By contrast, these aspects are considered under oligopolistic competition.

where the mark-up is given by

$$\mu_{i,t} = \frac{(1-\lambda_{i,t})\zeta}{(1-\lambda_{i,t})\zeta - 1} = \frac{\zeta}{\zeta - \frac{1}{1-\lambda_{i,t}}} \tag{2.24}$$

Equation (2.24) implies that if the market share of the single bank tends to zero, we end up with the special case of monopolistic competition where the mark-up, $\mu_{i,t}$, is constant since $\partial R_t^L / \partial r_{i,t}^L \to 0 \Leftrightarrow \lambda_{i,t} \to 0$.[18] Due to the assumption of oligopolistic competition it however follows that even in the case of completely flexible loan rates the mark-up of a bank i is non-stationary.

Empirical studies have however shown that the loan rate is rigid [see amongst others Henzel et al. (2009) or Gerali et al. (2010)]. We thus extend our framework by assuming quadratic loan rate adjustment costs, LAC_t, in the spirit of Rotemberg (1982) which are given by:

$$LAC_t \equiv \frac{\kappa^b}{2}\left(\frac{r_{i,t}^L}{r_{i,t-1}^L} - 1\right)^2 O_t \tag{2.25}$$

where κ^b can for instance be interpreted as menu costs.[19]

The intertemporal optimization of a bank's profit with respect to the loan rate, $r_{i,t}^L$, under sticky loan rates then results in[20]

$$r_{i,t}^L = \frac{(1-\lambda_{i,t})\zeta}{(1-\lambda_{i,t})\zeta - 1} R_t^B - \frac{\kappa^b}{(1-\lambda_{i,t})\zeta - 1}\psi_{i,t} \tag{2.26}$$

where

$$\psi_{i,t} \equiv \left[\frac{r_{i,t}^L}{r_{i,t-1}^L} - 1\right]\frac{r_{i,t}^L}{r_{i,t-1}^L}\frac{O_t}{o_{i,t}} - \beta E_t \left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left[\frac{r_{i,t+1}^L}{r_{i,t}^L} - 1\right]\frac{r_{i,t+1}^L}{r_{i,t}^L}\frac{O_{t+1}}{o_{i,t}}\right\} \tag{2.27}$$

By setting $\kappa^b = 0$, we would end up with (2.23).

2.2.5 Bank Creation

For modelling bank entry and exit, we apply a mechanism which is analogous to the firm entry model of Ghironi and Melitz (2005) and Bilbiie, Ghironi, and Melitz (2007a,b).[21]

By assumption, there exists an unbounded mass of potential banks which want to enter the market if their entry is profitable. Before entry, entrants have to pay a

[18] The mark-up would then be given by $\zeta/(\zeta-1) = const$.

[19] Naturally, these costs are rather small in the banking sector. Gerali et al. (2010) estimate the menu costs of firms to be more than three times larger than those in the loan markets.

[20] See the Appendix for a proof

[21] See amongst others Colciago and Etro (2010a,b) and Faia (2009) for firm entry models with oligopolistic competition in the goods market.

sunk cost. These costs are assumed to be proportional to the real marginal costs, i.e. the real interest rate, $\widetilde{R}_t^B \equiv R_t^B / E_t\pi_{t+1}$.[22] This implies that new banks are created by using deposits. We further assume a time-to-build lag in new bank creation. This assumption finds support in the data since the correlation between the mass of banks in $t+1$ and GDP in t is even larger [0.51] than the contemporaneous cross-correlation. This finding is totally analogous to firm entry data [see amongst others Devereux, Head, and Lapham (1996) or Totzek (2010)].

The following zero-profit condition determines the mass of entrants by aligning bank value, v_t, with the entry cost, f_E:

$$v_t = f_E \widetilde{R}_t^B \tag{2.28}$$

where the value of a bank is given by the present value of future profits, i.e. the discounted sum of future profits:

$$v_t = E_t \left\{ \sum_{s=t+1}^{\infty} \Delta_{t,s}(1-\delta)^{s-t} d_s \right\} \tag{2.29}$$

or equivalently[23]

$$v_t = (1-\delta)\beta E_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (v_{t+1} + d_{t+1}) \right\} \exp\{u_t^v\} \tag{2.30}$$

where $\delta \in (0,1)$ denotes the death probability of a bank.

Due to the assumption of a time-to-build lag, banks only consider future profits in their entry decision. In order to analyze exogenous changes in the value of banks, we add an autoregressive shock process, u_t^v, to (2.30) which follows: $u_t^v = \rho^v u_{t-1}^v + \varepsilon_t^v$ where ε_t^v is white noise.

As in the firm entry model of Bilbiie, Ghironi, and Melitz (2007a,b), we assume the recursive law of motion of the mass of banks to be given by

$$N_{t+1} = (1-\delta)(N_t + N_{E,t}) \tag{2.31}$$

[22] In Bilbiie, Ghironi, and Melitz (2007a,b) firms have to pay entry costs proportional to the effective real wage, i.e. their marginal costs.

[23] Equation (5.15) is the forward solution of (2.30):

$$\begin{aligned} v_t &= (1-\delta)E_t\left\{\Delta_{t,t+1}(v_{t+1}+d_{t+1})\right\} \\ &= (1-\delta)E_t\left\{\Delta_{t,t+1}([(1-\delta)\Delta_{t+1,t+2}(v_{t+2}+d_{t+2})]+d_{t+1})\right\} \\ &= (1-\delta)E_t\left\{\Delta_{t,t+1}d_{t+1}\right\} + (1-\delta)^2 E_t\left\{\Delta_{t,t+2}(v_{t+2}+d_{t+2})\right\} \\ &= (1-\delta)E_t\left\{\Delta_{t,t+1}d_{t+1}\right\} + (1-\delta)^2 E_t\left\{\Delta_{t,t+2}d_{t+2}\right\} + (1-\delta)^3 E_t\left\{\Delta_{t,t+3}d_{t+3}\right\} + \ldots \\ &= E_t\left\{\sum_{s=t+1}^{\infty}\Delta_{t,s}(1-\delta)^{s-t}d_s\right\} \end{aligned}$$

where $\Delta_{t,t+1} \cdot \Delta_{t+1,t+2} = \beta \frac{U_{C,t+1}}{U_{C,t}} \cdot \beta \frac{U_{C,t+2}}{U_{C,t+1}} = \beta^2 \frac{U_{C,t+2}}{U_{C,t}} = \Delta_{t,t+2}$, $\Delta_{t,t+3} = \Delta_{t,t+2} \cdot \Delta_{t+2,t+3}$, and $E_t U_{C,t+i} = E_t C_{t+i}^{-\sigma}$.

where $N_{E,t}$ denotes the mass of new banks. Equation (2.31) states that a fraction, δ, of incumbent and new banks is hit by an exogenous death shock at the very end of each period.[24]

2.2.6 Aggregation

Symmetry across banks implies $o_{i,t} = o_t$ and $r^L_{i,t} = r^L_t$. According to (2.12) and (2.13) we then obtain

$$O_t = N_t^{\frac{\zeta}{\zeta-1}} o_t \tag{2.32}$$

$$R^L_t = N_t^{\frac{1}{1-\zeta}} r^L_t \tag{2.33}$$

An increasing mass of banks ceteris paribus results in a rise in aggregate loans and in a decline in the loan rate.

Inserting (2.32) and (2.33) in equation (2.22) yields

$$\lambda_{i,t} = \lambda_t = \frac{1}{N_t} \tag{2.34}$$

implying that the market share of the single bank declines if the mass of banks increases. This in turn implies that the mark-up of a bank – also under flexible loan rates – decreases if the mass of banks rises. Since $\mu_{i,t} = \mu_t$ and

$$\mu_t = \frac{(N_t - 1)\zeta}{(N_t - 1)\zeta - N_t} \tag{2.35}$$

we obtain[25]

$$\frac{\partial \mu_t}{\partial N_t} = -\frac{\zeta}{[(N-1)\zeta - N]^2} < 0 \tag{2.36}$$

Our model thus draws an endogenous causality between the mass of operating banks and their mark-up which captures the corresponding negative correlation that we observed in the data [cf. Figure 2.2].

The real marginal costs of firms are given by equation (2.9). Inserting (2.23), (2.33), and (2.35) yields

$$mc_t = N_t^{\frac{1}{1-\zeta}} \frac{(N_t - 1)\zeta}{(N_t - 1)\zeta - N_t} \frac{R^B_t w_t}{A_t} \tag{2.37}$$

[24] Naturally, the assumption of a constant exit rate is a simplification. However, we show in Chapter 3 in a model with simultaneous *firm* entry and exit that the qualitative results do not change when endogenizing the firm exit rate. Instead, he points out that the assumption of simultaneous endogenous entries and exits just results in a marginal amplification effect when compared to the case of endogenous entries but exogenous exits. Further note that we relax the assumption of a constant death rate of banks by introducing an endogenous survival probability of new banks to the model in Section 2.3.1.

[25] Note that the mark-up, μ_t, is larger than one if $N_t > \zeta/(\zeta - 1)$. We calibrate ζ to 6 implying that $N_t > 1.2$. The numerically computed steady state value of N_t is 1.4.

implying that beside the pure cost channel, i.e. the direct influence of the nominal interest rate, there exists an *endogenous* cost-push shock resulting from endogenous bank entry and exit of oligopolistic competitors and their non-stationary mark-ups. Consequently, an expansionary reaction of the mass of operating banks leads to a decline in the firms' marginal costs since

$$\begin{aligned}\frac{\partial mc_t}{\partial N_t} &= \left[\frac{1}{1-\zeta} N_t^{\frac{1}{1-\zeta}-1} \frac{(N_t-1)\zeta}{(N_t-1)\zeta - N_t} - N_t^{\frac{1}{1-\zeta}} \frac{\zeta}{[(N-1)\zeta - N]^2}\right] \frac{R_t^B w_t}{A_t} \\ &= -N_t^{\frac{1}{1-\zeta}} \left[\left(\frac{1}{\zeta-1}\frac{N_t-1}{N_t} + \frac{1}{(N_t-1)\zeta - N_t}\right) \frac{\zeta}{(N_t-1)\zeta - N_t}\right] \frac{R_t^B w_t}{A_t} < 0 \qquad (2.38)\end{aligned}$$

since $N_t > \zeta/(\zeta-1) > 1 \Leftrightarrow (N_t-1)\zeta - N_t > 0$.

Aggregate production is given by[26]

$$Y_t = C_t + G_t + \frac{\kappa^f}{2}(\pi_t - 1)^2 Y_t \qquad (2.39)$$

G_t is government spending following an AR(1) process given by: $G_t/G = (G_{t-1}/G)^{\rho^g}$ $\exp\{\varepsilon_t^g\}$ where ε_t^g is white noise. We moreover define GDP as aggregate production plus investment

$$Y_t^{GDP} \equiv Y_t + N_{E,t} v_t \qquad (2.40)$$

where $N_{E,t} v_t$ is interpreted as investment in new banks.[27]

The loan market clearing condition follows

$$O_t = w_t L_t + N_t \frac{\kappa^b}{2}\left[\frac{r_t^L}{r_{t-1}^L} - 1\right]^2 O_t \qquad (2.41)$$

The model is closed by a monetary policy rule of Taylor type

$$\frac{R_t^M}{R^M} = \left(\frac{\pi_t}{\pi}\right)^{\lambda_\pi} \left(\frac{Y_t}{Y}\right)^{\lambda_y} \exp\{u_t^m\} \qquad (2.42)$$

where u_t^m is a shock to monetary policy which follows an AR(1) process: $u_t^m = \rho^m u_{t-1}^m + \varepsilon_t^m$ where ε_t^m is white noise.

The complete New Keynesian model with endogenous entry of oligopolistic banks can be found in Table 2.1.

2.2.7 Calibration

As standard in the literature, we set the private discount factor, β, to 0.99 implying a steady state of the annual nominal interest rate of about 4%. We calibrate both the

[26] The term $\frac{\kappa^f}{2}(\pi_t - 1)^2 Y_t$ results from the assumption of quadratic price adjustment costs which are paid in terms of the consumption good.

[27] An equivalent definition can be found in Bilbiie, Ghironi, and Melitz (2007a,b).

$$\theta - 1 = \theta mc_t - \kappa^f E_t \left\{ (\pi_t - 1)\pi_t - \beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} (\pi_{t+1} - 1)\pi_{t+1} \frac{Y_{t+1}}{Y_t} \right\}$$
$$mc_t = R_t^L \frac{w_t}{A_t}$$
$$C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} \frac{R_t^B}{\pi_{t+1}} \right\}$$
$$w_t = \chi C_t^\sigma L_t^\eta$$
$$Y_t = A_t L_t$$
$$Y_t = C_t + G_t + \frac{\kappa^f}{2} (\pi_t - 1)^2 Y_t$$
$$Y_t^{GDP} = Y_t + N_{E,t} v_t$$
$$\frac{R_t^M}{R^M} = \left(\frac{\pi_t}{\pi}\right)^{\lambda_\pi} \left(\frac{Y_t}{Y}\right)^{\lambda_y} \exp\{u_t^r\}$$
$$v_t = f_E E_t \left\{ \frac{R_t^B}{\pi_{t+1}} \right\}$$
$$N_t = (1 - \delta)(N_{t-1} + N_{E,t-1})$$
$$O_t = N_t^{\frac{\zeta}{\zeta - 1}} o_t$$
$$R_t^L = N_t^{\frac{1}{1-\zeta}} r_t^L$$
$$r_t^L = \frac{(1 - \lambda_t)\zeta}{(1 - \lambda_t)\zeta - 1} R_t^B - \frac{\kappa^b}{(1 - \lambda_t)\zeta - 1} \psi_t$$
$$\psi_t = \left[\frac{r_t^L}{r_{t-1}^L} - 1\right] \frac{r_t^L}{r_{t-1}^L} \frac{O_t}{o_t} - \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left[\frac{r_{t+1}^L}{r_t^L} - 1\right] \frac{r_{t+1}^L}{r_t^L} \frac{O_{t+1}}{o_t} \right\}$$
$$\mu_t = \frac{(N_t - 1)\zeta}{(N_t - 1)\zeta - N_t}$$
$$O_t = w_t L_t + N_t \frac{\kappa^b}{2} \left[\frac{r_t^L}{r_{t-1}^L} - 1\right]^2 O_t$$
$$v_t = (1 - \delta)\beta E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} (v_{t+1} + d_{t+1}) \right\}$$
$$d_t = (r_t^L - R_t^B) o_t$$
$$R_t^M = R_t^B$$
$$\lambda_t = 1/N_t$$

Table 2.1: *The complete New Keynesian model with endogenous entry of oligopolistic banks*

intertemporal elasticity and the Frisch elasticity of labor supply to one which is also standard. In particular, this implies that log consumption enters the utility function. As in Smets and Wouters (2007), we set the steady state government spending/GDP ratio to 18% which is moreover the value calculated by Trabandt and Uhlig (2009) for the US economy. The intratemporal elasticity between intermediate goods, θ, is set to 11 implying a steady state mark-up of 10% in the goods market. The price stickiness parameter, κ^f, is assumed to be 77 as estimated in Ireland (2001). We moreover abstract from trend inflation, i.e. $\overline{\pi} = 1$.

The elasticity between the loans, ζ, is calibrated to 6 in order to obtain an equivalent ζ/θ-ratio as in Gerali et al. (2010). When assuming the loan rates to be sticky, we moreover set the loan rate stickiness parameter, κ^b, to 22.43 in order to obtain the same slope of the loan rate equation, $(\zeta - 1)/\kappa^b$, as estimated in Gerali et al. (2010). When assuming loan rates to be flexible, κ^b is zero. We calibrate the bank death rate, δ, to the empirically observed value, 0.013.[28] To match the data appropriately, we set the entry costs, f_E, to 6. The scaling parameter, χ, is endogenously determined by the steady state system to ensure that in steady state total hours worked is 1/3. We moreover apply a standard Taylor rule, with $\lambda_\pi = 1.5$ and $\lambda_y = 0.125$.

Finally, we calibrate the shock processes to the estimated values of Smets and Wouters (2007), i.e. we respectively set the persistence of the shock to technology, to government spending, and to the interest rate to 0.95, 0.97, and 0.15. The corresponding standard errors are 0.45, 0.53, and 0.24, respectively. Without loss of generality, we assume the shock to bank value to occur with a shock persistence of 0.95. The corresponding standard error is normalized to 0.01.

2.2.8 The Benchmark New Keynesian Model

In order to obtain an appropriate benchmark for our analysis, we apply a standard New Keynesian model with a cost channel. The model is characterized by a completely competitive banking sector whose mass is constant and normalized to one. As a result, the banks do not ask for a mark-up such that $R_t^L = R_t^B$. The complete benchmark model can be found in Table 2.2. For the sake of comparability, we apply the same calibration as for the bank entry model.

$$\theta - 1 = \theta mc_t - \kappa^f E_t \left\{ (\pi_t - 1)\pi_t - \beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} (\pi_{t+1} - 1)\pi_{t+1} \frac{Y_{t+1}}{Y_t} \right\}$$

$$mc_t = R_t^B \frac{w_t}{A_t}$$

$$C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} \frac{R_t^B}{\pi_{t+1}} \right\}$$

$$w_t = \chi C_t^\sigma L_t^\eta$$

$$Y_t = A_t L_t$$

$$Y_t = C_t + G_t + \frac{\kappa^f}{2}(\pi_t - 1)^2 Y_t$$

$$\frac{R_t^M}{R^M} = \left(\frac{\pi_t}{\pi}\right)^{\lambda_\pi} \left(\frac{Y_t}{Y}\right)^{\lambda_y} \exp\{u_t^r\}$$

$$R_t^B = R_t^M$$

Table 2.2: *The complete benchmark New Keynesian model*

2.2.9 Stability Analysis

Surico (2008) provides the necessary and sufficient conditions for determinacy for our benchmark model, the New Keynesian model with a cost channel and a standard Taylor rule. Llosa and Tuesta (2009) and Brückner and Schabert (2003) moreover

[28] The data is provided by the Federal Deposit Insurance Corporation.

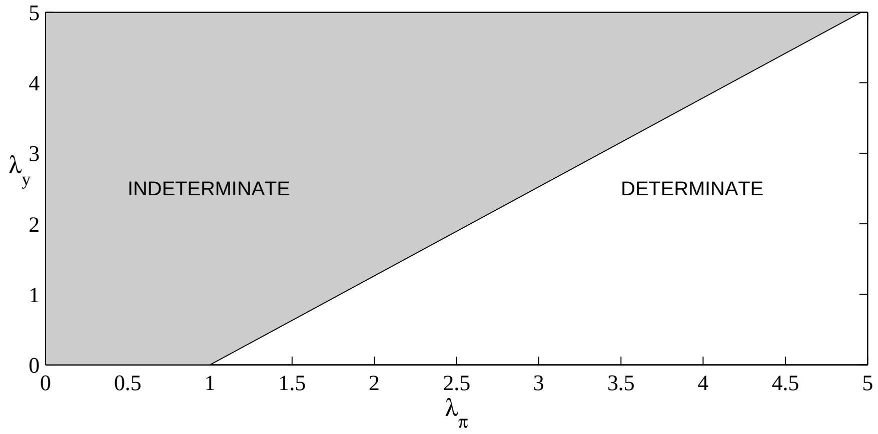

Figure 2.4: *Regions of determinacy*

study how different monetary policy rules may affect determinacy. The studies highlight that in contrast to the standard New Keynesian model, there exists an upper bound to the output reaction in the monetary policy rule if the cost channel is existent.

Figure 2.4 shows the regions of determinacy for the bank entry model. In comparison with the findings of Surico (2008), the figure indicates that the region of determinacy remains approximately unaffected. In particular, this implies that also in our framework, there exists an upper bound to λ_y which increases if $\lambda_\pi \geq 1$ is increased.

2.3 Impulse Responses

2.3.1 The Technology Shock

In this section, we will investigate the impulse responses to an expansionary technology shock. Thereby, we will analyze the impact of the loan rate rigidity and the survival probability of new banks. In the following, we will refer to the model specification with *flexible* loan rates and *exogenous* exits as the *baseline* bank entry model.

The Baseline Bank Entry Model

Figure 2.5 shows the impulse responses to an aggregate technology shock of the baseline bank entry model.[29]

In line with empirical evidence of amongst others Smets and Wouters (2003, 2007),

[29] We simulate the model in non-linear form using Dynare V.4. The corresponding steady state system is numerically computed by an own Matlab file. They are shown in the Appendix. The number of years are on the abscissa. However, we interpret periods as quarters. On the ordinate we plot the percentage deviation of a variable from the corresponding steady state value, i.e. $x_t = (X_t - \overline{X})/\overline{X}$, where $\overline{X}$ is the steady state value.

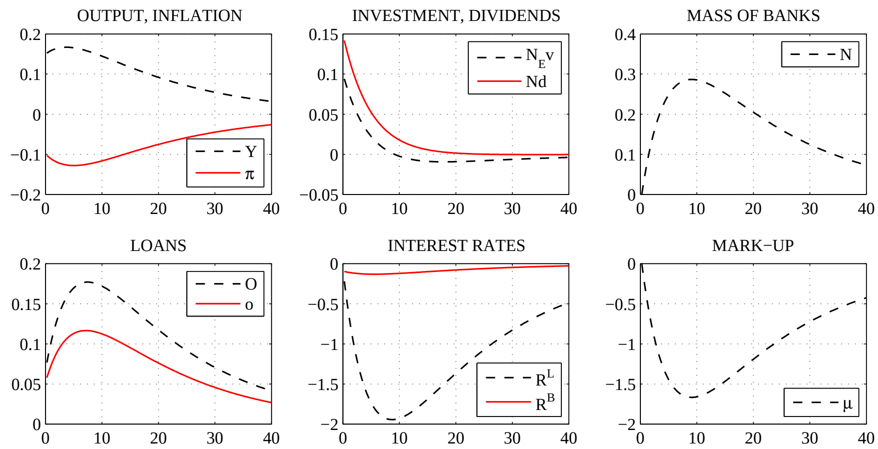

Figure 2.5: *Impulse responses to an expansionary technology shock*

the innovation causes inflation to decrease while output increases. Since firms have to pre-finance their wage-bill, the demand for loans reacts expansionary, too. The drop in the nominal interest rate moreover leads to a decline in the marginal costs of banks. All in all, the profit opportunities of banks increase which cause new banks to enter the market and consequently induces a boom in investment in new banks. The latter effect is moreover amplified by the decline in the nominal interest rate which leads to lower entry costs. In Section 3.2, we come to this point into more detail.

The expansionary reaction of the mass of operating banks leads to a drop in the market share of the single banks [cf. equation (2.34)]. Consequently, banks decrease their mark-ups. As already mentioned, the mark-up of banks acts as an endogenous cost-push shock [cf. equation (2.37)] which reacts expansionary in this case. The declining mark-up thus results in a drop in firms' marginal costs which leads to a further increase in production and consequently in loan demand. As a result, the endogenous bank mark-up introduces a multiplier effect, the new financial accelerator.

In order to measure the quantitative size of our financial accelerator, Figure 2.6 shows the impulse responses to an aggregate technology shock of the baseline bank entry model (dashed lines) in comparison with the benchmark New Keynesian model (solid lines).

When comparing the quantitative effects of both models, it turns out that the new financial accelerator leads to a significant propagation in the reaction of output. This effect is even more pronounced in the case of GDP since investment in new banks additionally increases [cf. Figure 2.5].

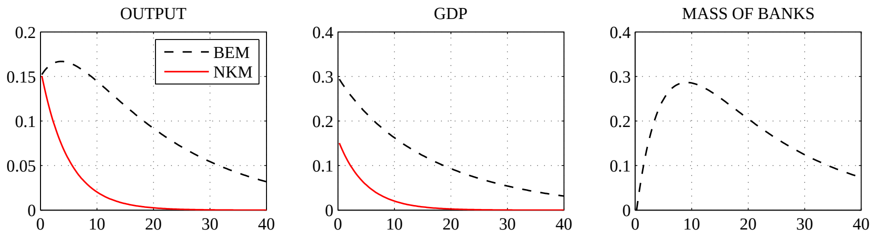

Figure 2.6: *Impulse responses of the baseline bank entry model (BEM) to an expansionary technology shock in comparison with the benchmark New Keynesian model (NKM)*

The financial accelerator in our model is driven by two effects. First, due to the declining mark-up the contractionary reaction of the loan rate is more pronounced in the bank entry model leading to lower marginal costs for firms. Second, investment in new banks is a component of GDP. All in all, endogenizing the mass of oligopolistic banks leads a significant amplification effect. Moreover, Figure 2.6 shows that the reactions in the bank entry model turn out to be more persistent, too. Our framework is thus a further step to solve the puzzle how relatively small shocks can result in large and persistent effects for the real economy [see amongst others Mankiw (2001), Chari et al. (2000), and Fuhrer and Moore (1995)].

When comparing the quantitative accelerating effects with BGG, it turns out that our model generates even higher amplification effects than the famous financial accelerator model. BGG conclude that their financial accelerator model generates about 50% amplification of the initial reaction of GDP.[30] Figure 2.6 however indicates that the assumption of an endogenous mass of oligopolistic banks results in an initial amplification effect of about 100%.

All in all, our model is able to capture the empirical findings that (i) bank mark-ups react counter-cyclical and (ii) the positive co-movement of the mass of banks with GDP and to generate significant amplification and persistence effects.

The Bank Entry Model with Sticky Loan Rates

Up to now, we have assumed that loan rates are flexible. However, there exists empirical evidence that loan rates are rigid [see amongst others Henzel et al. (2009) or Gerali et al. (2010)]. Figure 2.7 shows the impulse responses to an aggregate technology shock under flexible (solid lines) and under sticky loan rates (dashed lines).

The figure indicates that the introduction of sticky loan rates as a further nominal rigidity does not make much difference for the resulting dynamics. The reaction of

[30] Note however that Christensen and Dib (2008) estimate a New Keynesian model incorporating the BGG framework for the US. They show that the presence of a financial accelerator mechanism à la BGG significantly amplifies the impact of demand-side shocks but dampens the rise of investment to a shock to technology.

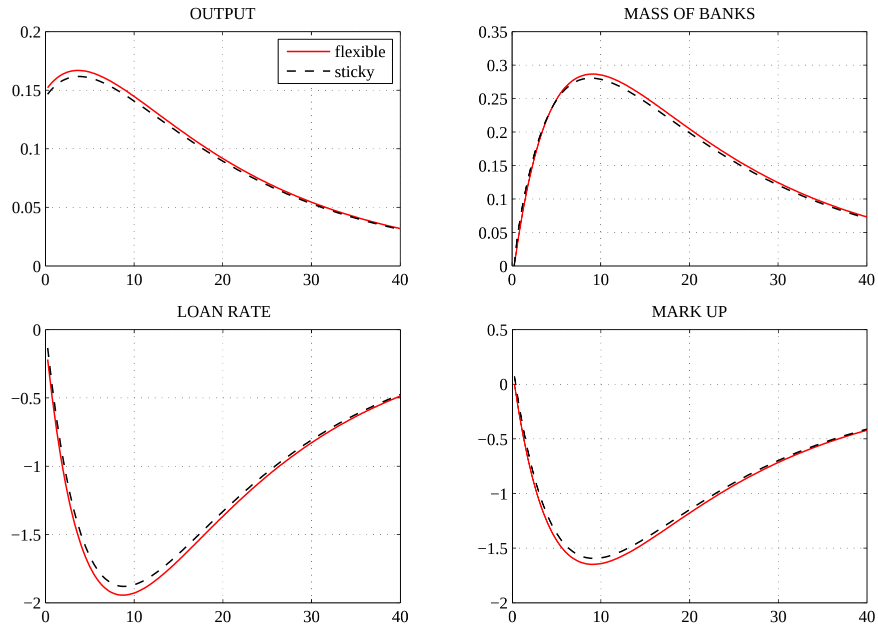

Figure 2.7: *Impulse responses to an expansionary technology shock with sticky loan rates in comparison with the baseline model with flexible loan rates*

the loan rate becomes naturally somewhat smoother. However, when compared to the case of flexible loan rates the resulting dynamics of the mass of banks and GDP do not differ significantly. The reactions are just slightly less expansionary.

The Bank Entry Model with an Endogenous Survival Probability of New Banks

For the sake of simplicity, we have assumed exits to be exogenous as in the firm entry models of amongst others Bilbiie, Ghironi, and Melitz (2007a,b).[31] For the following exercise, we want to abstract from this assumption and alternatively assume that the survival probability for new banks depends negatively on the mass of new start ups.[32] Applying this assumption on the mass of banks in the market, results in:

$$N_{t+1} = (1-\delta)(N_t + F(N_{E,t}/N_{E,t-1})) \tag{2.43}$$

with $F(N_{E,t}/N_{E,t-1}) \equiv [1 - S(N_{E,t}/N_{E,t-1})]N_{E,t}$ where $S(\cdot)$ has the following properties: $S(1) = S'(1) = 0$ and $S''(1)$ is constant and strictly positive.[33] Technically, this mechanism is similar to investment adjustment costs as for instance assumed in Christiano, Eichenbaum, and Evans (2005).

[31] See Totzek (2010) or Chapter 3 for a model with a microfounded incentive-based mechanism of simultaneous endogenous firm entry and exit.

[32] An equivalent mechanism can be found in the extended firm entry model à la Bilbiie, Ghironi, and Melitz (2007a,b) outlined in Lewis (2009b).

[33] When setting $S(\cdot) = 0 \Leftrightarrow F(\cdot) = N_{E,t}$, we end up with our baseline model.

We further assume $S''(1) = 2.48$ which is the value that Christiano, Eichenbaum, and Evans (2005) estimate for capital investment adjustment costs. A function which fulfills these properties is given by

$$F(N_{E,t}, N_{E,t-1}) = \left[1 - 1.24\left(\frac{N_{E,t}}{N_{E,t-1}} - 1\right)^2\right] N_{E,t} \qquad (2.44)$$

The impulse responses to an expansionary technology shock are shown in Figure 2.8 in comparison with the baseline bank entry model and the benchmark New Keynesian model. We assume the loan rate to be flexible again.

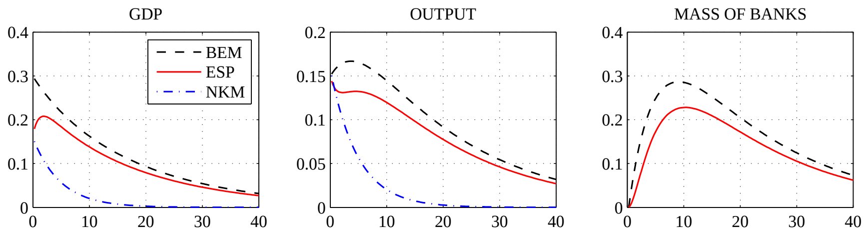

Figure 2.8: *Impulse responses to an expansionary technology shock with an endogenous survival probalitity (ESP) in comparison with the baseline bank entry model (BEM) and the benchmark New Keynesian Model (NKM)*

Figure 2.8 indicates that the assumption of an endogenous survival probability of new banks has quantitative and qualitative effects for the resulting dynamics. The endogenous survival probability of new banks which increases in the mass of start-ups naturally dampens the expansionary reaction of the mass of banks. Moreover, we can now generate a hump-shaped adjustment pattern in GDP which naturally comes at the costs of a lower impact reaction and thus of a smaller initial financial accelerator. Note however that the model still generates a significant amplification and persistence effect in GDP and output when compared to the benchmark New Keynesian model.

2.3.2 The Interest Rate Shock: A New Transmission Channel for Monetary Policy

In this section, we will describe our new transmission channel for monetary policy. In order to differentiate this concept from that of the traditional financial accelerator model, we start by illustrating the transmission channel in BGG.

BGG integrate the Bernanke, Gertler, and Gilchrist (1996) approach into a New Keynesian model. Hence, they build up an overlapping generations model where firms need physical capital and labor for production. The acquisition of capital is financed either by borrowing or by entrepreneurial net wealth. Financial intermediaries ask for an external finance premium (or: mark-up) over their marginal costs for providing capital. This mark-up is not caused by an imperfectly competitive environment of financial institutions but by the assumption of information asymmetries across borrowers and lenders. BGG moreover assume that the external finance premium inversely depends on borrowers net wealth. The transmission channel for monetary policy in BGG now works as follows. An easing of monetary policy increases the return on capital resulting in an increase in the net wealth of firms. This in turn causes a decrease in firm leverage leading to a reduction of the external finance premium and thus to a further rise in capital demand.

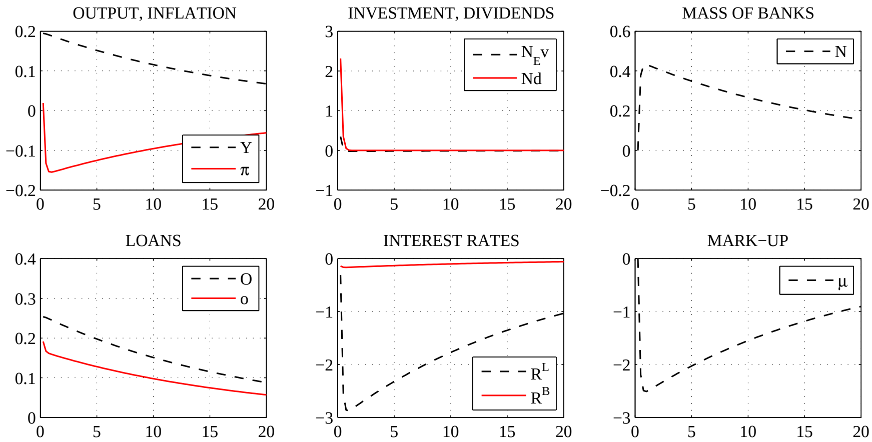

Figure 2.9: *Impulse responses to an expansionary shock to the interest rate*

In contrast to BGG, we do not emphasize the mark-up movements from the demand side of credit. Instead, our financial accelerator nests from the supply side. A decrease in the nominal interest rate results in four expansionary effects. (i) consumption is shifted to the present leading to a higher loan demand. (ii) the marginal costs of banks decrease.[34] (iii) bank entry costs decline, too. (iv) the decrease in the real stochastic discount factor causes the value of a bank to increase. The first two effects result in higher bank profits while the latter two effects have moreover an expansionary impact on the profitability of bank start-ups. This in turn results in an increase in investment in new banks. The resulting expansionary reaction of the mass of operating banks then leads to a declining mark-up in the loan market.[35] Since firms have to pre-finance their wage-bill, a decreasing mark-up has a positive effect on their marginal costs leading to a further increase in production and thus in loan demand.[36] This in turn induces the new financial accelerator. Figure 2.9 shows the corresponding impulse responses.

[34] The marginal costs of banks are simply given by the nominal deposit rate, $R_t^B = R_t^M$.

[35] Note that the latter effect is absent when assuming monopolistic competition since then the bank mark-up would not decrease when new banks enter the market.

[36] Remark: Under monopolistic competition the bank mark-up would be constant such that this expansionary effect would not occur.

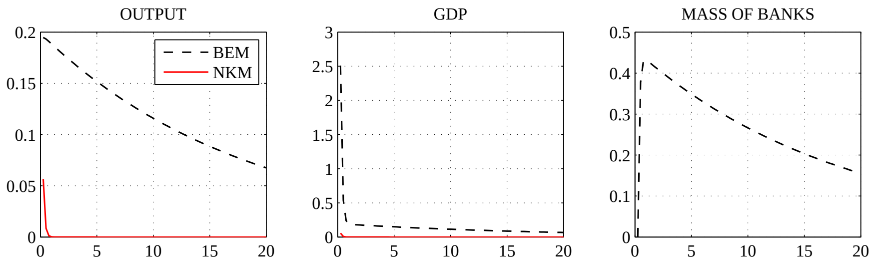

Figure 2.10: *Impulse responses of the baseline bank entry model (BEM) to an expansionary shock to monetary policy in comparison with the benchmark New Keynesian model (NKM)*

Figure 2.10 shows that the endogenous bank entry mechanism leads to a significant amplification effect when compared to the benchmark New Keynesian model. The effect is again larger than that generated by the financial accelerator in BGG. BGG only generate an amplification effect of about 50%. By contrast, the shock results in much larger propagation effects with respect to output and GDP in our framework. As Figure 2.9 depicts, the easing in monetary policy results in a massive increase in investment in new banks. This in turn amplifies the boom in GDP. Moreover, our bank entry model again generates significantly more persistent dynamics.

2.3.3 The Shock to Government Spending

In this section, we will analyze a shock to government spending. For this exercise, we deviate from our baseline calibration and assume that the monetary authority follows a Taylor rule with the original coefficients of Taylor (1993), i.e. $\lambda_\pi = 1.5$ and $\lambda_y = 0.5$. Figure 2.11 shows the corresponding impulse responses. At the end of this section, we will investigate how monetary policy affects the results.

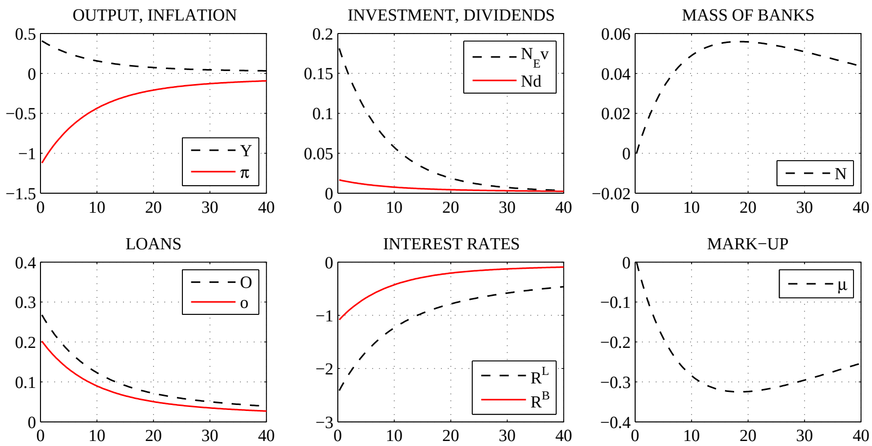

Figure 2.11: *Impulse responses to an expansionary shock to government spending*

Figure 2.11 shows that output and loan demand increase. The drop in the nominal interest rate lowers the marginal costs of banks. Consequently, the shock generates additional profit opportunities for existing and potential banks. This in turn leads to higher investments and thus to an increasing mass of banks. In comparison with the shock to monetary policy and to total factor productivity, the expansionary reaction of the mass of operating banks is however about ten times smaller.

In comparison with the benchmark model, Figure 2.12 shows that the bank entry model generates only small amplification effects with respect to output and GDP. The rationale is the comparatively small expansionary reaction of the mass of banks and consequently that the drop in bank mark-ups turns out to be rather small [cf. Figure 2.11]. The amplification of output and GDP respectively amount to 36% and 46%. The latter approximately corresponds with the amplification effect in BGG.

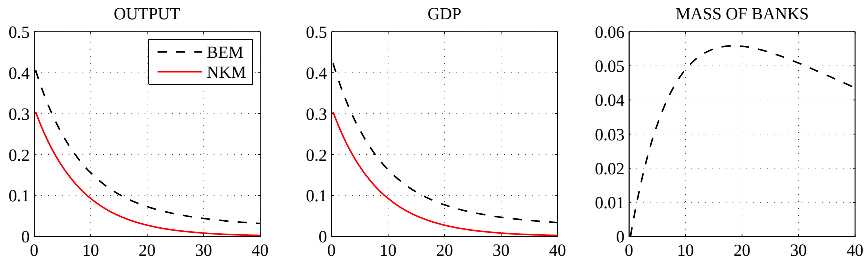

Figure 2.12: *Impulse responses of the baseline bank entry model (BEM) to an expansionary shock to government spending in comparison with the benchmark New Keynesian model (NKM)*

Figure 2.11 shows that the fiscal demand stimulus leads to a decline in inflation which is ad odds with the empirical evidence of amongst others Smets and Wouters (2007, 2003). However, Linnemann and Schabert (2003) show within the baseline New Keynesian model that the qualitative reaction of inflation crucially depends on the design of monetary policy. In particular, the Taylor rule coefficient λ_y is the decisive factor. Linnemann and Schabert (2003) show that inflation only increases if $\lambda_y = 0$.

Figure 2.13 indicates that we obtain exactly the same result in our framework. As in the baseline New Keynesian model without a cost channel, inflation and the nominal interest rate only increase if $\lambda_y = 0$. However and in contrast to the standard New Keynesian model, the cost channel leads to a more expansionary reaction of output if the monetary authority reacts to output, too, i.e. if $\lambda_y > 0$. The rationale is that the reaction of the nominal interest rate causes the marginal costs of firms to decrease. Consequently, $\lambda_y > 0$ has a positive impact on production via the cost channel. This result holds in both the bank entry model and the benchmark New Keynesian model.

In the bank entry model, a drop in the interest rate moreover leads to a downward pressure on the entry costs. Inversely, an increase in the interest rate leads to an

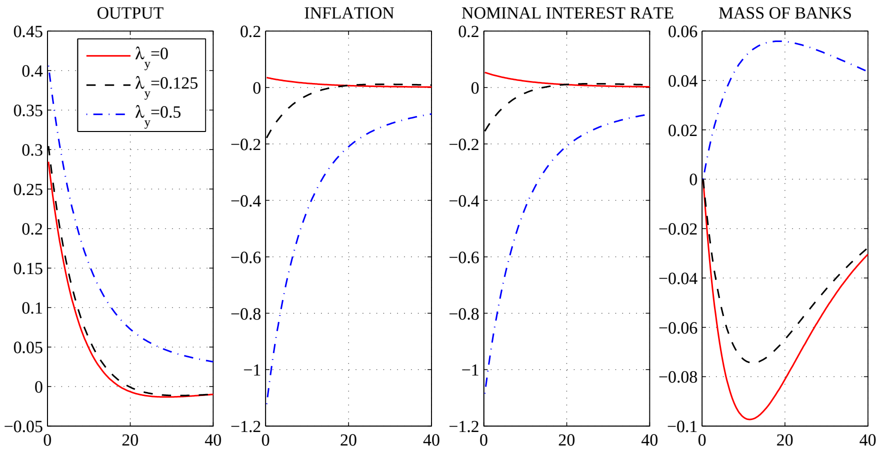

Figure 2.13: *On the impact of monetary policy*

increase in the entry costs. This is the case for $\lambda_y = 0$ and for $\lambda_y = 0.125$ in the longer-run. As Figure 2.13 depicts, the reaction of output moreover turns negative in the longer-run if $\lambda_y \in \{0, 0.125\}$. This naturally dampens the profit opportunities of incumbent and new banks. The development of the mass of banks consequently indicates that the additional profit opportunities only cover the entry costs, if $\lambda_y \geq 0.5$. Otherwise, the mass of banks declines.[37]

2.3.4 The Shock to Bank Value

As a consequence of the subprime bust in 2007, banks around the globe lost in value. Since we apply a rather simple model, we exogenously add such a value shock to equation (2.30). Figure 2.14 shows the corresponding impulse responses. In contrast to the previously analyzed shocks, the shock to bank value does not directly affect the real economy, i.e. the goods market. Instead, it only has a direct impact on the entry decision of new banks. The spill-over to the real economy consequently occurs only via mark-up movements in the banking sector, i.e. the endogenous cost push shock.

As entering the market becomes less profitable for new banks, investment in new banks decreases. Since the mass of banks reacts contractionary, the mark-up of banks increases [cf. equation (2.38)] leading to higher marginal costs for firms. The resulting endogenous cost-push shock consequently reacts contractionary in this case [cf. equation (2.36)]. The shock to bank value thus leads to stagflation.

Figure 2.14 however shows that inflation initially declines before the reaction turns

[37]This result is in line with the findings of Totzek and Winkler (2010) who show within an estimated firm entry model that the reaction of the mass of firms is ambiguous in the case of a fiscal demand shock whereas it is unambiguous for other shocks, as for instance a technology shock [see also Chapter 5].

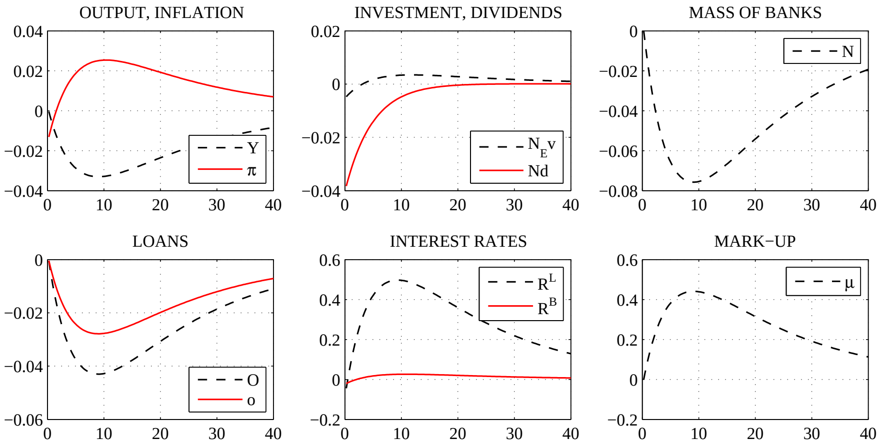

Figure 2.14: *Impulse responses to a contractionary shock to bank value*

positive. However, this result is driven by monetary policy. As the mass of banks decreases, the declining mark-up leads to an upward-pressure on the loan rate and thus on inflation. By contrast, the expansionary monetary policy reaction decreases the marginal costs of banks leading to a downward-pressure on inflation.

All in all, this exercise shows that in line with the observation in the financial crisis 2007-2009 (and previous financial crisis, too) banks do not only propagate shocks but can also be the source of macroeconomic disturbances.

2.4 Second Moments

Business cycle models are traditionally evaluated by comparing the second moments of the generated series with those observed in the data [see amongst others King and Rebelo (1999)]. In this section, we thus want to report, how the presented model performs along this dimension. Moreover, we analyze the impact of the introduction of a financial transaction tax and a financial activity tax on the generated financial and macroeconomic volatility.

2.4.1 The Baseline Bank Entry Model

For this exercise, we simulate the reaction of the baseline bank entry model to the aggregate productivity shock 500 times for 500 quarters. We then discard the first 411 quarters to obtain the same sample size as in the data set.[38] We use the Hodrick-Prescott filter with a smoothing parameter of 10^5. It is worth mentioning that we

[38] The data set is described below.

do not deviate from our baseline calibration in this exercise.[39]

Table 2.3 reports the resulting moments of the baseline bank entry model[40] (normal numbers) and the resulting moments of the benchmark New Keynesian model (italic numbers in parenthesis). Moreover, Table 2.3 shows the values calculated from US data (bold numbers). The data range is 1988:Q1-2010:Q1 due to the restricted availability of the number of banks data. As a measure for loans and for the mark-up of a commercial bank, we respectively choose total loans and investments at all commercial banks and the spread between the average majority prime rate charged by banks on short-term loans to business and the FED's funds rate. The data for the remaining macroeconomic variables is standard.[41]

	Standard deviation σ_X			Relative standard deviation σ_X/σ_{GDP}			First-order autocorrelation $E_t(X_t, X_{t-1})$		
GDP	**1.23**	1.25	*(0.83)*	**1.00**	1.00	*(1.00)*	**0.89**	0.84	*(0.82)*
C	**1.04**	1.01	*(0.82)*	**0.85**	0.81	*(0.98)*	**0.87**	0.86	*(0.82)*
I	**5.01**	2.36	*(n.a.)*	**4.08**	1.89	*(n.a.)*	**0.93**	0.83	*(n.a.)*
w	**1.02**	1.43	*(1.01)*	**0.83**	1.14	*(1.22)*	**0.79**	0.89	*(0.82)*
O	**1.89**	1.88	*(n.a.)*	**1.54**	1.51	*(n.a.)*	**0.82**	0.90	*(n.a.)*
o	**1.71**	1.71	*(n.a.)*	**1.39**	1.37	*(n.a.)*	**0.78**	0.91	*(n.a.)*
N	**0.45**	0.25	*(n.a.)*	**0.37**	0.20	*(n.a.)*	**0.83**	0.96	*(n.a.)*
μ	**0.33**	0.85	*(n.a.)*	**0.27**	0.67	*(n.a.)*	**0.87**	0.96	*(n.a.)*

Table 2.3: *Business cycle statistics [***data***, bank entry model, (benchmark New Keynesian model)]*

Table 2.3[42] shows that the introduction of our financial accelerator leads to a significant amplification of the generated standard deviations. This result is in line with Jermann and Quadrini (2009) who show that the introduction of a financial sector leads to an important propagation of macroeconomic volatility.[43] Moreover, the generated standard deviations in both absolute and relative terms are very close to the empirically observed ones. By contrast, the benchmark New Keynesian model does not generate enough volatility in output and consumption.

Naturally, a further advantage of the bank entry model is that we can additionally analyze the moments of financial variables. Table 2.3 reports that the model

[39] As standard in the literature, we compute the first-order autocorrelations and standard deviation in absolute and relative terms. The latter is defined as the standard deviation of a variable divided by the standard deviation of GDP.

[40] In line with the impulse response analysis of Section 2.3.1, the introduction of loan rate stickiness does not significantly alters the generated second moments. In particular, they are virtually indistinguishable.

[41] The data for loans, the loan rate, and the number of banks is provided by the Board of the Governors of the Federal Reserve System. The data for the standard macroeconomic variables is taken from the US department of Commerce (Bureau of Economic Analysis) and the US Department of Labor.

[42] Remark: The benchmark New Keynesian model does neither include financial variables such as O_t, o_t, N_t, or μ_t nor investment in new banks, I_t. Consequently, we cannot calculate the corresponding second moments of these variables. In Table 2.3 we thus state n.a. (not available).

[43] Remark: Jermann and Quadrini (2009) develop a model with explicit roles for debt and equity financing and analyze shocks that affect the firms' capacity to borrow. They moreover show that the additional introduction of financial shocks lead to a further amplification effect. This also holds true in our framework when for instance considering a shock to loan demand.

performs surprisingly well with respect to this dimension, too. The model does not only generate an appropriate volatility of aggregate loans and loans per bank but also depicts the comparatively low volatilities of the mass of operating banks. The generated price-cost margin is however too volatile. With respect to the first-order autocorrelation, the bank entry model even generates too much endogenous persistence of the financial variables under consideration. The generated autocorrelations of GDP, consumption, and the real wage are slightly larger when compared to the benchmark New Keynesian model.

2.4.2 The Financial Activity Tax and the Financial Transaction Tax

As Table 2.3 depicts, the existence of the financial sector leads to higher volatilities for key macroeconomic variables. In order to extenuate the additional source of economic instability, we will now investigate the effects resulting from the introduction of two financial taxes.[44] The most prominent taxes being discussed by politicians in this context – especially in the Euro Area – are the so-called 'financial activity tax' and the 'financial transaction tax'. The respective tax bases are profits and transactions.

In the case of a financial activity tax, the bank has to pay a tax, τ_t^d, on profits. In our framework this implies according to (2.17):

$$d_{i,t} = (1 - \tau_t^d)(r_{i,t}^L - R_t^B)o_{i,t} \tag{2.45}$$

The financial activity tax does not affect the optimal loan rate decision. Since the tax however dampens per period profits, it has a negative effect on bank value and thus on bank entry.

An alternative tax which is especially proposed by German policy makers is the financial transaction tax (or: Tobin (1978) tax) where a bank has to pay a tax, $\widetilde{\tau}_t^d$, on each transaction. In our simple banking model, a bank makes only a single transaction each period by providing an amount of loans $o_{i,t}$ to firms. The profit of a bank is then given by

$$d_{i,t} = (r_{i,t}^L - R_t^B)o_{i,t} - \widetilde{\tau}_t^d o_{i,t} \tag{2.46}$$

In contrast to the financial activity tax, the financial transaction tax has an effect on the optimal loan rate decision since it affects the marginal costs of banks. The optimal loan rate is now given by

$$r_{i,t}^L = \frac{(1-\lambda_{i,t})\zeta}{(1-\lambda_{i,t})\zeta - 1}(R_t^B + \widetilde{\tau}_t^d) \tag{2.47}$$

[44] Remark: In standard DSGE macro models, profit taxation is lump-sum, i.e. such tax changes do not affect the resulting dynamics, at all. By contrast, taxes on profits are not lump-sum when considering an endogenous mass of oligopolistic banks.

Since new banks have to pay entry costs proportional to their marginal costs, the free entry condition must also be modified correspondingly.

As a consequence, the financial transaction tax results in two negative effects on bank entry and thus on the new financial accelerator. First, it dampens per period profits of banks via additional tax costs. Second, the tax raises the marginal costs of banks and consequently entry costs. This implies that in line with the findings of Lengnick and Wohltmann (2010) the financial transaction tax seems to be more effective in decreasing the volatilities on financial markets and the resulting accelerator effects for the real economy.

In order to extenuate the additional source of economic instability, we now want to find the specific level of the financial activity tax rate and the financial transaction tax rate which decreases the macroeconomic volatility to that of our benchmark model where our financial accelerator is not existent. For the sake of comparability, we assume that both tax increases occur with the same degree of persistence as the technology shock.

Figure 2.15 reports the standard deviation of GDP for different tax levels. The dashed black lines indicate the standard deviation of GDP which the benchmark New Keynesian model generates, 0.83.

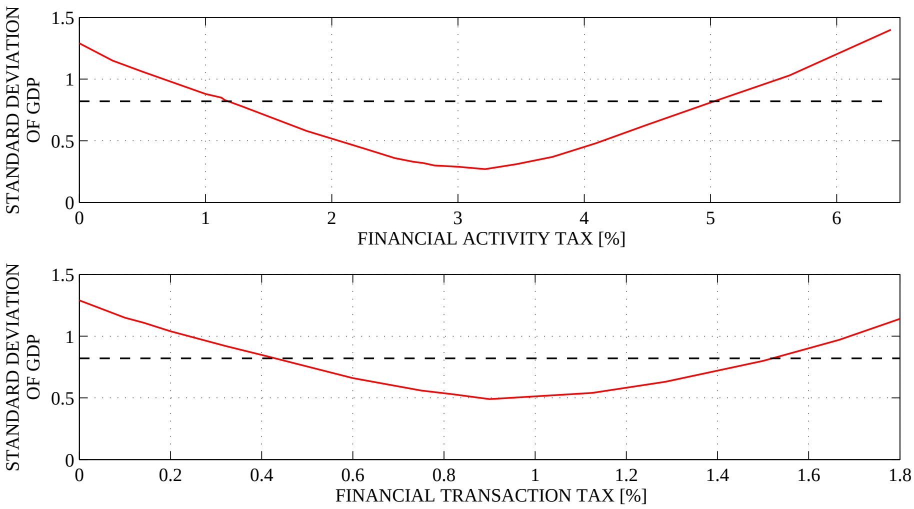

Figure 2.15: *The impact of the financial activity tax and the financial transaction tax on the standard deviation of GDP*

Figure 2.15 shows that both financial taxes perform qualitatively equivalent. Small increases in the tax level lead to a decline in macroeconomic volatility, whereas increases above a certain threshold lead to a rise in macroeconomic volatility. This result is in line with Lengnick and Wohltmann (2010).[45] Figure 2.15 moreover indicates that the financial transaction tax has significantly larger effects. In the case of the financial activity tax, a tax level of 1.15% is needed to achieve the same volatility level as in the benchmark model without bank entry and oligopolistic competition. By contrast, there is only need for a financial transaction tax of about 0.41% to generate the same volatility of GDP. This implies that the additional effect of the latter tax on banks' marginal costs leads to a three times larger impact on the volatility of GDP.[46]

Table 2.4 reports the second moments of the baseline bank entry model without a financial tax (bold numbers) in comparison with the case of a financial activity tax [1.15%] (normal number) and a financial transaction tax [0.41%] (italic number in parenthesis).

	Standard deviation σ_X			Relative standard deviation σ_X/σ_{GDP}			First-order autocorrelation $E_t(X_t, X_{t-1})$		
GDP	**1.25**	0.83	*(0.83)*	**1.00**	1.00	*(1.00)*	**0.84**	0.82	*(0.82)*
C	**1.01**	0.85	*(0.83)*	**0.81**	1.02	*(1.00)*	**0.86**	0.83	*(0.81)*
I	**2.36**	0.75	*(0.85)*	**1.89**	0.90	*(1.02)*	**0.83**	0.82	*(0.82)*
w	**1.43**	1.09	*(1.02)*	**1.14**	1.31	*(1.22)*	**0.89**	0.83	*(0.82)*
O	**1.88**	1.15	*(1.04)*	**1.51**	1.39	*(1.25)*	**0.90**	0.84	*(0.82)*
o	**1.71**	1.12	*(1.03)*	**1.37**	1.35	*(1.24)*	**0.91**	0.83	*(0.82)*
N	**0.25**	0.07	*(0.02)*	**0.20**	0.08	*(0.02)*	**0.96**	0.96	*(0.96)*
μ	**0.85**	0.26	*(0.05)*	**0.67**	0.31	*(0.06)*	**0.96**	0.96	*(0.96)*

Table 2.4: *Business cycle statistics of the* **baseline bank entry model***,* the bank entry model with financial activity tax *[1.15%], (the bank entry model with financial transaction tax [0.41%])*

Table 2.4 indicates that both taxes are not only able to reduce the volatility of GDP to the benchmark level but also the volatilities of the other variables under consideration. In fact, the generated moments of the benchmark New Keynesian model and that of the bank entry model with financial taxes are very close to each other. Table 2.4 moreover shows that both financial taxes are appropriate to dampen the volatilities in the financial markets, too. In particular, the standard deviation of the mass of operating banks significantly declines. This effect is especially pronounced in case of the financial transaction tax where the mass of operating banks and consequently the bank mark-up turns out to be approximately constant.[47]

[45] Lengnick and Wohltmann (2010) moreover show that the u-shaped impact of both taxes also holds when considering other measures of volatility.

[46] Note however that these values seem to be rather large. For instance the Swedish government introduces a financial transaction taxes between 0.003% and 0.5% in the 1980s.

[47] When assuming lower taxes, the mark-up naturally becomes more volatile again.

2.5 Conclusion

In order to capture the empirical findings that the number of banks significantly co-moves with GDP and that bank mark-ups react counter-cyclical, we develop a New Keynesian macro model which incorporates an oligopolistic banking sector with endogenous bank entry.

We find that the resulting model generates counter-cyclical mark-up movements in the banking sector and large amplification and persistence effects. More precisely, we obtain accelerating effects which are significantly larger than those generated by the famous study of BGG. In particular, we obtain very large accelerating effects in the case of a monetary policy shock. These results are robust with different assumptions concerning the loan rate rigidity and the death rate of new banks.

Moreover, we show that banks do not only propagate shocks but can also be the source of financial disturbances which have important implications for the real economy. Therefore, we analyze the implications of a contractionary shock to bank value which leads to stagflationary effects for the real economy.

We finally evaluate our model by comparing the second moments of the generated series with those observed in US data. The analysis shows that the bank entry model performs remarkable well. More precisely, the model does not only depict the properties of key macroeconomic variables appropriately but also of financial variables including the mass of banks, the amount of aggregate loans, and the amount of loans per banks.

Moreover, we analyze the macroeconomic implications of a financial activity tax and a financial transaction tax. Our analysis points out that these two taxes are indeed an appropriate tool to stabilize the financial markets and thus to dampen the volatility of key macroeconomic variables. We find that the financial activity tax where banks have to pay a tax on each transaction is about three times more effective than the financial transaction tax where the tax base is simply per period profits.

Future work should concern about simultaneous bank and firm entry. This give rise to further amplifications and interesting results with respect to the interdependency between financial and real markets. Moreover, we show that our model generates an endogenous cost-push shock resulting from oligopolistic competition. This implies a non-trivial role for monetary policy also in the case of a technology shock or a shock to the interest rate that – in contrast to a(n exogenous) cost-push shock – do not generate a trade-off between stabilizing inflation and output in the standard New Keynesian model. Future work could thus concern about optimal monetary policy in such an environment.

Appendix

Derivation of (2.26):

Under sticky loan rate the maximization problem of a bank is given by

$$\max_{r^L_{i,t}} \quad E_0 \sum_{t=0}^{\infty} \Delta_{0,t} \left\{ (r^L_{i,t} - R^B_t) o_{i,t} - \frac{\kappa^b}{2} \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right)^2 O_t \right\} \tag{A.2.1}$$

$$\text{s.t.} \quad o_{i,t} = \left(\frac{r^L_{i,t}}{R^L_t} \right)^{-\zeta} O_t \tag{A.2.2}$$

The maximization yields

$$\begin{aligned}
&\Delta_{0,t} \left\{ o_{i,t} + (r^L_{i,t} - R^B_t) \left[(-\zeta) \frac{(r^L_{i,t})^{-\zeta-1}}{(R^L_t)^{-\zeta}} O_t + \zeta \frac{(r^L_{i,t})^{-\zeta}}{(R^L_t)^{-\zeta+1}} O_t \frac{o_{i,t}}{O_t} \right] \right. \\
&\left. -\kappa^b \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right) O_t \frac{1}{r^L_{i,t-1}} \right\} + \kappa^b E_t \left\{ \Delta_{0,t+1} \left(\frac{r^L_{i,t+1}}{r^L_{i,t}} - 1 \right) O_{t+1} \frac{r^L_{i,t+1}}{(r^L_{i,t})^2} \right\} = 0 \\
\Leftrightarrow \quad &\Delta_{0,t} \left\{ o_{i,t} + (r^L_{i,t} - R^B_t) \left[(-\zeta) \frac{o_{i,t}}{r^L_{i,t}} + \zeta \frac{o_{i,t}}{R^L_t} \frac{o_{i,t}}{O_t} \right] \right. \\
&\left. -\kappa^b \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right) O_t \frac{1}{r^L_{i,t-1}} \right\} + \kappa^b E_t \left\{ \Delta_{0,t+1} \left(\frac{r^L_{i,t+1}}{r^L_{i,t}} - 1 \right) O_{t+1} \frac{r^L_{i,t+1}}{(r^L_{i,t})^2} \right\} = 0
\end{aligned} \tag{A.2.3}$$

Multiplying by $r^L_{i,t}/(\Delta_{0,t} o_{i,t})$ yields

$$\begin{aligned}
&r^L_{i,t} + (r^L_{i,t} - R^B_t) \left[(-\zeta) + \zeta \frac{r^L_{i,t} o_{i,t}}{R^L_t O_t} \right] - \kappa^b \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right) \frac{O_t}{o_{i,t}} \frac{r^L_{i,t}}{r^L_{i,t-1}} \\
&\qquad + \kappa^b E_t \left\{ \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \left(\frac{r^L_{i,t+1}}{r^L_{i,t}} - 1 \right) \frac{O_{t+1}}{o_{i,t}} \frac{r^L_{i,t+1}}{r^L_{i,t}} \right\} = 0 \\
\Leftrightarrow \quad &r^L_{i,t}[1 - \zeta(1 - \lambda_t)] - R^B_t \zeta [\lambda_{i,t} - 1] - \kappa^b \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right) \frac{O_t}{o_{i,t}} \frac{r^L_{i,t}}{r^L_{i,t-1}} \\
&\qquad + \kappa^b E_t \left\{ \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \left(\frac{r^L_{i,t+1}}{r^L_{i,t}} - 1 \right) \frac{O_{t+1}}{o_{i,t}} \frac{r^L_{i,t+1}}{r^L_{i,t}} \right\} = 0 \\
\Leftrightarrow \quad &r^L_{i,t} = \frac{\zeta[\lambda_{i,t} - 1]}{1 - \zeta(1 - \lambda_{i,t})} R^B_t + \frac{\kappa^b}{1 - \zeta(1 - \lambda_{i,t})} \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right) \frac{O_t}{o_{i,t}} \frac{r^L_{i,t}}{r^L_{i,t-1}} \\
&\qquad - \frac{\kappa^b}{1 - \zeta(1 - \lambda_{i,t})} E_t \left\{ \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \left(\frac{r^L_{i,t+1}}{r^L_{i,t}} - 1 \right) \frac{O_{t+1}}{o_{i,t}} \frac{r^L_{i,t+1}}{r^L_{i,t}} \right\}
\end{aligned}$$

$$
\begin{aligned}
\Leftrightarrow \quad r^L_{i,t} = & \frac{\zeta[1-\lambda_{i,t}]}{\zeta(1-\lambda_{i,t})-1} R^B_t \\
- & \frac{\kappa^b}{\zeta(1-\lambda_{i,t})-1} \underbrace{\left\{ \left(\frac{r^L_{i,t}}{r^L_{i,t-1}} - 1 \right) \frac{O_t}{o_{i,t}} \frac{r^L_{i,t}}{r^L_{i,t-1}} - E_t \left\{ \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \left(\frac{r^L_{i,t+1}}{r^L_{i,t}} - 1 \right) \frac{O_{t+1}}{o_{i,t}} \frac{r^L_{i,t+1}}{r^L_{i,t}} \right\} \right\}}_{\psi_{i,t}}
\end{aligned}
\tag{A.2.4}
$$

where $\lambda_{i,t} = \frac{r^L_{i,t} o^L_{i,t}}{R^L_t O^L_t}$ and $\frac{\Delta_{0,t+1}}{\Delta_{0,t}} = \beta \left(\frac{E_t C_{t+1}}{C_t} \right)^{-\sigma}$.

Steady State Values

N	1.40	C	0.27	G	0.06	L	0.33	N_E	0.02	R^M	1.01
R^D	1.01	R^L	2.24	GDP	0.45	Y	0.33	A	1.00	mc	0.91
o	0.10	π	1.00	r^L	2.41	d	0.14	O	0.13	μ	2.39

Table 2.5: *Numerically computed steady state values*

3 Firms' Heterogeneity, Endogenous Entry and Exit Decisions

3.1 Introduction

The number of producing firms varies over time and significantly co-moves with GDP [see amongst others Devereux, Head, and Lapham (1996) or Bergin and Corsetti (2008)]. Moreover, the empirical study of Campbell (1998) shows that, although the entry rate of new firms is significantly correlated with GDP, the co-movement between the business cycle and firms' failures is even larger.[1] This result is confirmed by Jaimovich and Floetotto (2008) who also find negative and highly significant correlations between GDP and firms' failures based on industry level data. However, in the recent theoretical macroeconomic literature an endogenous tendency for firms to leave the market has been neglected, yet. The substantial cyclical behavior of firms' failures implies that a closer examination of this topic may help to explain how shocks to the economy generate large and persistent business cycle fluctuations.

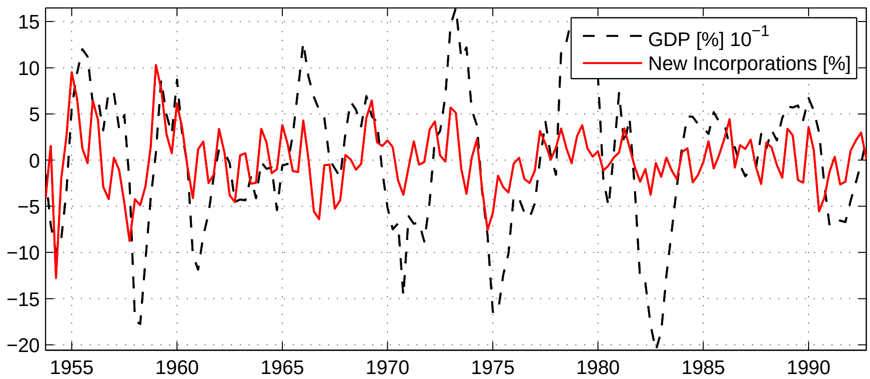

Figure 3.1: *Firm birth rate and GDP in the US (Hodrick-Prescott filtered data in logs)*

Figure 3.1 and Figure 3.2 depict new incorporations and firm failures in comparison with GDP for the US economy based on quarterly data (1953Q1:1992Q4 and 1953Q1:1998Q4), respectively.[2] The data is represented in logs and de-trended by application of the Hodrick-Prescott filter. Figure 3.1 and Figure 3.2 indicate that

[1]Campbell (1998) finds a correlation between the exit (entry) rate and GDP growth of 0.51 (0.28) for the US economy (1972Q2-1988Q4).

[2]The data of new incorporations and firms' failures is provided by the "Survey of Current Business" and the "Economic Report of the President" by the Council of Economic Advisors.

there exists a positive (negative) co-movement of firm creations (failures) with GDP.

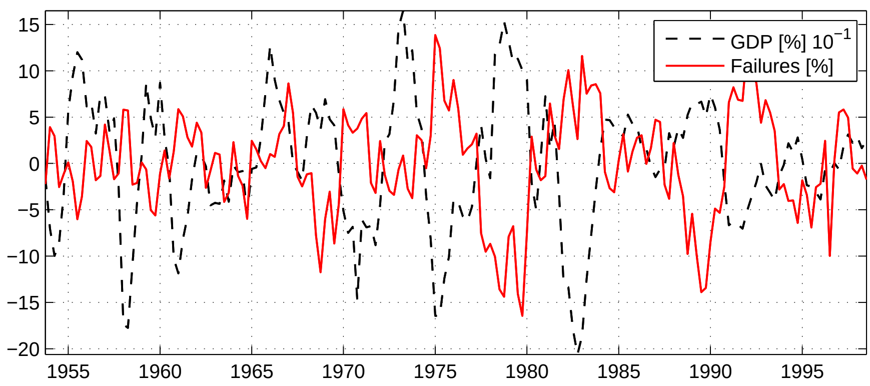

Figure 3.2: *Firm failures and GDP in the US (Hodrick-Prescott filtered data in logs)*

Figure 3.3 depicts the corresponding cross-correlations between GDP and firm failures as well as between GDP and new incorporations for different leads and lags. It shows that although firm creation is strongly correlated with GDP (0.41), an even stronger (negative) correlation exists between GDP and firm failures (-0.57). This result is consistent with the findings of Campbell (1998) and is moreover analogous to labor market data where job destruction turns out to be more cyclical than job creation [see Blanchard and Diamond (1990) or Davis and Haltiwanger (1992)]. It is additionally worthwhile to mention that in line with the results of Devereux, Head, and Lapham (1996), entries take place slightly prior to an increase in GDP while exits take place contemporaneously.

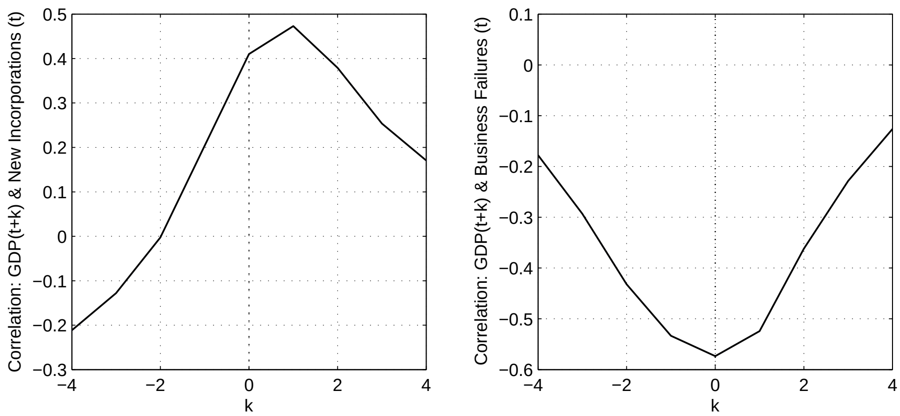

Figure 3.3: *Cyclical properties of firm entry and exit*

There exists a small but growing strand of literature dealing with endogenous firm entries initiated by Ghironi and Melitz (2005) and Melitz (2003) to which Jaimovich and Floetotto (2008), Bilbiie, Ghironi, and Melitz (2007a) [henceforth: BGMa], Corsetti, Martin, and Pesenti (2007), and Beaudry, Collard, and Portier (2006) have contributed some interesting aspects on business cycle movements and the extensive margin of production.[3] By introducing nominal rigidities to the framework of BGMa, the study of Bilbiie, Ghironi, and Melitz (2007b) [henceforth: BGMb] has become the workhorse New Keynesian model for analyzing monetary policy issues in a framework with endogenous firm entry [see e.g. Faia (2009), Bergin and Corsetti (2008), Lewis (2009a,b), and Elkhoury and Mancini-Griffoli (2006)]. However, the authors mentioned above assume that the firms' death rate is constant over time. More precisely, they assume that with a given (constant) probability firms are hit with a death shock at the very end of each period. By contrast, Lewis (2009b) extends the model of BGMb by assuming an endogenous but ad hoc survival probability of new firms. She shows that this extension has important implications for the resulting dynamics in response to a monetary policy shock. Lewis (2009b) claims that rethinking the way how firm entries and exits are modelled is thus of great interest.

The purpose of this chapter[4] is therefore to provide an alternative microfounded firm entry and exit mechanism within a New Keynesian model with heterogeneous firms. We assume the firms to be heterogeneous with respect to their individual productivity. They thus produce with different technologies. Thereby, both the entry and exit decisions of firms are based on present value criteria. More precisely, if on the one hand an existing firm expects a non-positive present value of current and future production, it will consequently leave the market. On the other hand, a new firm will enter, if its entry is profitable, i.e. if the present value of production exceeds the entry costs. Of course, the entry and exit decisions crucially depend on the respective individual productivity level in our model. This implies that similar to Hopenhayn (1992), good (i.e. productive) firms will thus stay in the market or will enter it, while bad firms will leave.

Our framework has several advantages in comparison with BGMa and BGMb. Especially in the case of monetary and fiscal interventions our model is more conclusive in some important economic aspects. More precisely, the model of BGMb generates a decrease in the mass of producers in the case of an expansionary shock to monetary policy. This however conflicts with the empirical insights of Bergin and Corsetti (2008). Their VAR analysis shows that a decrease in the interest rate encourages firm entry. In line with this finding, our framework generates the suggested increase in the mass of products even in a simplified specification of the model where exits are assumed to be exogenous. The economic intuition is that due to heterogeneity – also across potential firms – there will always exist a firm with an individual pro-

[3] In the following, the use the expression "extensive margin" and "mass of firms" synonymously.

[4] For a different version of this chapter see "Firms' Heterogeneity, Endogenous Entry, and Exit Decisions", Dec. 2009, Economics Working Paper 2009-11, Department of Economics, Christian-Albrechts-Universität Kiel.

ductivity level that is only slightly too low for a profitable entry. As a consequence, also small expansionary shocks can result in an increase in the extensive margin. When assuming homogeneity across firms as in BGMa and BGMb, this result does not have to hold.

Moreover and as respectively shown by Lewis (2009b) and Totzek and Winkler (2010), the frameworks of BGMb and BGMa do not deliver an unambiguous reaction of the mass of producers in the case of an expansionary fiscal shock. Instead, the qualitative reaction of the mass of firms is very sensitive to the autocorrelation of the shock process and the labor supply elasticity of the households. Varying these parameters within an empirically plausible range can cause the mass of firms to decline leaving other variables qualitatively unchanged. However, the empirical analysis of Lewis (2009b) indicates that fiscal demand shocks unambiguously stimulate firm entry. Our framework turns out to be more robust with respect to this aspect since it generates an unambiguous increase in the mass of producers for plausibly assumed labor supply elasticities and it generates an increase in the mass of producers for a larger range of degree of shock persistence.

A further advantage of our framework is that it can capture the empirically observed counter-cyclicality of firm exits [cf. Figure 3.2]. Moreover, the framework can easily be extended by capital in production and in product creation under a standard calibration.[5]

A further problem of the models of Bilbiie, Ghironi, and Melitz (2007a,b) is that they do *not* perform better than standard RBC models with respect to the generated second moments [see Bilbiie, Ghironi, and Melitz (2007a,b)]. By contrast, our model performs better since it solves two problems of standard New Keynesian and RBC models. First, in our approach total hours worked and consumption do not react too smooth relative to output.[6] Second, all variables do not behave too pro-cyclical.[7] When assuming firm exits to be exogenous or prices to be completely flexible, results become worse. Hence, an endogenous tendency of firms to leave the market should not be neglected.

In addition, our model can contribute to the debate in the RBC literature initiated by Galí (1999), whether an overall productivity shock leads to an expansionary or contractionary reaction of aggregate labor. In the empirical literature, there is a widespread agreement that there exists a *negative* correlation between total hours worked and GDP [see amongst others Francis and Ramey (2004, 2005), Galí and

[5]As already mentioned by BGMa, their framework delivers implausible and oscillating impulse responses if the depreciation rate is below 50% which is at odds with the data.

[6]Remark: In standard New Keynesian and RBC models the ratio of the generated standard deviation of hours worked and GDP is too low when compared to the empirically observed value. The same holds true for consumption [cf. King and Rebelo (1999)].

[7]Remark: In standard New Keynesian and RBC models the generated autocorrelation coefficients are too large when compared to the empirically observed ones [cf. King and Rebelo (1999)].

Rabanal (2004), and Galí (1999)]. However, standard RBC models generate a *positive* co-movement. By making prices totally flexible and considering capital, the resulting RBC core of our model can depict both possibilities when the intertemporal elasticity of substitution is varied within an empirically plausible range.[8] The underlying driving force is the development of the extensive margin, i.e. the mass of producing firms.

As producer price index (PPI) and consumer price index (CPI) inflation do not coincide in general in our approach, we derive two specifications of the Phillips curve. We show that PPI inflation is only affected by expected future inflation and the labor share as in the baseline Phillips curve. This result is moreover supported by US economy data as there does not exist a significant correlation between PPI inflation and the extensive margin. In the case of CPI inflation, there however exists a variety effect in our theoretical framework since the CPI Phillips curve is also a function of the change in the mass of producers. This is moreover supported by US economy data since we find that CPI inflation is significantly correlated with the change in the mass of producers.[9] We estimate the latter specification of the Phillips curve using the generalized method of moments (GMM). We show that the impact of the change in the extensive margin on CPI inflation is highly significant in the reduced form as well as in the structural estimation. In comparison with the baseline New Keynesian Phillips curve our CPI Phillips curve becomes flatter in an inflation/labor share-space. This implies that the introduction of an endogenous mass of producers causes the impact of the labor share on inflation to decrease since there occur additional effects from changes in the mass of firms.

The remaining chapter is organized as follows. In section 3.2, we develop the totally microfounded New Keynesian model with endogenous firms' entries and exits. Section 3.3 provides our baseline calibration. The resulting impulse responses to persistent shocks to aggregate technology, to the interest rate, and to government spending are discussed in section 3.4. In section 3.5, we compare the generated second moments of our model with those of BGMa and with the data. The GMM estimations of the resulting Phillips curves are done in section 3.6. The last section concludes.

[8] Remark: Within a classical monetary model, i.e. in an RBC framework without capital in production, the sign of the reaction of hours worked crucially depends on the intertemporal elasticity of substitution [cf. Galí (2008, Ch.2)]. However, when considering capital in the model, hours worked always react expansionary [cf. Galí (1999)].

[9] The corresponding correlation is -0.13 at a 95% significance level.

3.2 The Model

3.2.1 Producers

Following amongst others Christoffel, Kuester, and Linzert (2009), Faia, Lechthaler, and Merkl (2010a), and Lechthaler, Merkl, and Snower (2010), we assume three sectors of production in order to separate the pricing decision under nominal rigidities from the input factor demand. We will distinguish between intermediate good producers, firms in the wholesale sector, and retailers.

The intermediate good producers (or: firms) differ in their individual productivity level. They are thus heterogeneous. Due to firm entries and exits the mass of intermediate goods (or: products) is variable over time.[10] The mass of producing firms in t is denoted with N_t. The intermediate good is sold to the wholesale sector under flexible prices.

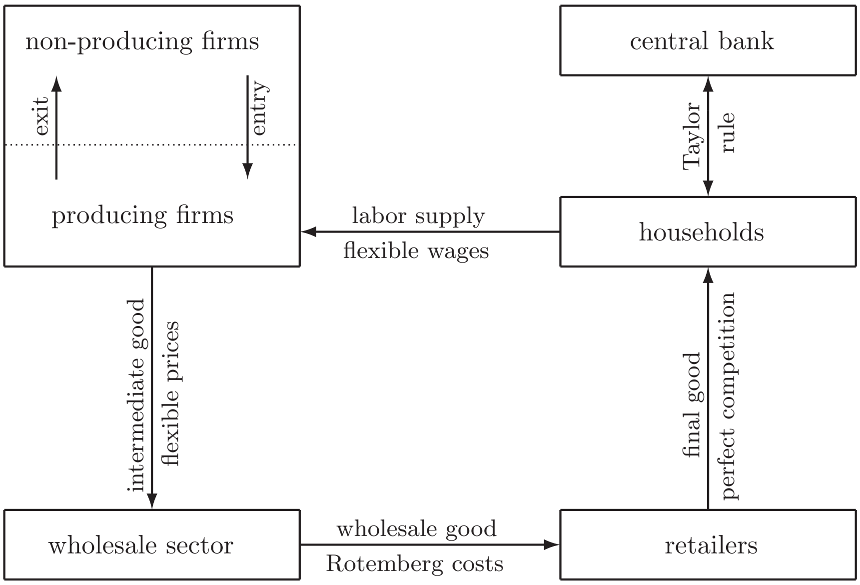

Figure 3.4: *Model structure*

Firms in the wholesale sector differentiate the intermediate goods using a CES technology and sell them to the retail sector under monopolistic competition.[11] They are moreover faced with quadratic adjustment costs in the spirit of Rotemberg (1982). Eventually, the final good producers (or: retailers) bundle the differentiated wholesale goods and sell them to the households under perfectly competitive conditions. The model structure is depicted in Figure 3.4.

[10] For the sake of simplicity, we assume a one-to-one identification between a product and a firm. As standard in the macroeconomic theory, we thus do not model multi-product firms.

[11] Technically, the wholesale sector is needed to simplify the aggregation.

Retail Sector

The retailer bundles the wholesale goods, $y^w_{j,t}$, according to the CES technology function given by

$$Y_t \equiv \left(\int_0^1 (y^w_{j,t})^{\frac{\zeta-1}{\zeta}} dj \right)^{\frac{\zeta}{\zeta-1}} \tag{3.1}$$

where $\zeta > 1$ denotes the elasticity between the wholesale goods. By cost minimization, we obtain the standard price index, P_t:

$$P_t = \left(\int_0^1 (P^w_{j,t})^{1-\zeta} dj \right)^{\frac{1}{1-\zeta}} \tag{3.2}$$

Wholesale Sector

The firms in the wholesale sector – indexed with $j \in (0,1)$ – differentiate the intermediate goods, $y_{i,t}$. The wholesale good is thus a bundle of mass N_t of intermediate goods, indexed with i. The corresponding CES technology of a wholesale firm is given by

$$y^w_{j,t} \equiv \left[\int_0^{N_t} y_{i,t}^{\frac{\zeta-1}{\zeta}} di \right]^{\frac{\zeta}{\zeta-1}} \tag{3.3}$$

which implies a price level given by

$$P^w_{j,t} = \left[\int_0^{N_t} P_{i,t}^{1-\zeta} di \right]^{\frac{1}{1-\zeta}} \tag{3.4}$$

For the sake of simplicity, we assume the same elasticity between intermediate and wholesale goods as well as between wholesale and final goods.

Being faced with quadratic adjustment costs in the spirit of Rotemberg (1982), the wholesale goods are sold to the retailers under monopolistic competition. The real profit of a wholesale firm j is then given by

$$E_0 \sum_{t=0}^{\infty} \Delta_{0,t} \left\{ \frac{P^w_{j,t}}{P_t} y^w_{j,t} - mc^w_{j,t} y^w_{j,t} - \frac{\theta^c}{2} \left(\frac{P^w_{j,t}}{P^w_{j,t-1}} - \overline{\pi}_j \right)^2 y^w_{j,t} \right\} \tag{3.5}$$

where $\Delta_{0,t}$ and $\overline{\pi}_j$ represent the stochastic real discount factor and the steady state value of producer price changes, respectively. $mc^w_{j,t}$ are the marginal costs. θ^c is interpreted as the menu costs resulting from relative price changes. E denotes the rational expectations operator.

Optimizing (3.5) subjected to the demand for the wholesale good, $y^w_{j,t} = \left(\frac{P^w_{j,t}}{P_t} \right)^{-\zeta} Y_t$, yields the Phillips curve in non-aggregated terms[12]

$$\rho_{j,t} = \frac{\zeta}{\zeta-1} mc^w_{j,t} - \frac{\theta^c}{\zeta-1}\left[(\pi_{j,t}-\overline{\pi}_j)\pi_{j,t} - E_t\left\{\frac{\Delta_{0,t+1}}{\Delta_{0,t}}(\pi_{j,t+1}-\overline{\pi}_j)\pi_{j,t+1}\frac{y^w_{j,t+1}}{y^w_{j,t}}\right\}\right] + \frac{\zeta}{\zeta-1}\frac{\theta^c}{2}(\pi_{j,t}-\overline{\pi}_j)^2 \tag{3.6}$$

where $\rho_{j,t} \equiv \frac{P^w_{j,t}}{P_t}$ and $\pi_{j,t} \equiv \frac{P^w_{j,t}}{P^w_{j,t-1}}$.

Intermediate good producers

The intermediate good producers are *heterogeneous*. Following Ghironi and Melitz (2005), we assume that these firms differ in their individual productivity denoted with z_i. They thus produce with *different* technologies. In contrast to Ghironi and Melitz (2005), we do *not* assume that firms are *identical* upon entry.[13] Instead, each firm has an individual productivity level independently whether it is actually producing or not.[14]

For production firms need labor. The production function of a firm i is given by

$$y_{i,t} = A_t z_i l_{i,t} \tag{3.7}$$

where $l_{i,t}$ represents the labor demand of firm i, respectively. A_t is an overall productivity shock. The individual productivity level, z_i, is assumed to be Pareto distributed across firms which fits firm level data quite well [see Ghironi and Melitz (2005)]. The probability distribution function (PDF) and the cumulative distribution function (CDF) of z_i then follow $k\frac{z_i^{-k-1}}{z_{\min}^{-k}}$ and $1-\left(\frac{z_i}{z_{\min}}\right)^{-k}$, respectively, where k and $z_{\min}$ are scaling parameters.[15]

Productivity differences across firms translate into differences in real marginal costs.

$$mc_{i,t} = \frac{w_t}{A_t z_i} \tag{3.8}$$

The intermediate good is sold to the wholesale sector under completely flexible prices and under monopolistic competition.

After observing the shocks, a non-producing firm will enter the market, if the market

[12] See the Appendix for a proof.

[13] Ghironi and Melitz (2005) assume that firms are homogeneous before entry. Upon entry, firms draw their individual productivity level in order to determine which producing firm will become an exporter. However, the assumption of heterogeneity across (producing) firms is not important for the entry mechanism in their approach.

[14] Naturally, this productivity is only potential if a firm is currently not producing. This productivity level holds when entering the market.

[15] $z_{\min} > 0$ moreover represents the minimal individual productivity level.

entry costs do not exceed the expected generated present value of production, i.e.[16]

$$\Psi_{i,t} = (\rho_{i,t} - mc_{i,t})\, y_{i,t} + \frac{E_t\{\Delta_{0,t+1}\}}{\Delta_{0,t}} E_t\left\{ \Psi_{i,t+1} | \left[z_i > \delta^{out}_{t+1}\right]\right\} \geq f_E mc_{i,t} \qquad (3.9)$$

where f_E denotes the proportionality constant of market entry costs which are assumed to be proportional to the marginal costs.[17] $E_t\left\{ \Psi_{i,t+1} | \left[z_i > \delta^{out}_{t+1}\right]\right\}$ is the expected next period profit conditional on being existent in the market. The productivity threshold, δ^{out}_t, denotes the specific individual productivity level, z_i, where a producing firm is indifferent between leaving the market or continuing production. Equivalently, there exists a productivity threshold, δ^{in}_t, where a non-producing firm is indifferent between entering the market and staying out. For $z_i = \delta^{in}_t$ inequality (3.9) holds with equality. This implies that only a firm with a sufficiently high individual productivity level ($z_i \geq \delta^{in}_t$) will generate positive profits which cover the entry costs and will thus enter the market.

After observing the shocks, an intermediate good producer which is currently existent in the market decides whether to stay or to leave the market before he actually starts producing.[18] If a firm exits the market, it has to pay bankruptcy costs.[19] The firm will thus exit, if the difference between its generated present value of production and the exit costs is non-positive. The proportionality constant of exit costs, f_X, are also assumed to be proportional to the marginal costs,[20] i.e.

$$\Psi_{i,t} = (\rho_{i,t} - mc_{i,t})\, y_{i,t} + \frac{E_t\{\Delta_{0,t+1}\}}{\Delta_{0,t}} E_t\left\{ \Psi_{i,t+1} | \left[z_i > \delta^{out}_{t+1}\right]\right\} \leq f_X mc_{i,t} \qquad (3.10)$$

When comparing (3.9) and (3.10), it directly follows that the productivity thresholds for entering and exiting the market, i.e. the specific individual productivity levels where (3.9) and (3.10) hold with equality, only coincide if $f_E = f_X$. As long as the entry costs exceed the exit costs, the productivity threshold for an entry is larger than the threshold for staying in the market. This implies that a higher individual productivity level is needed to enter the market than for staying. Empirically, this can be justified with the existence of barriers to entry.

The change in the mass of producing firms in the market, ΔN_t, is defined as the mass of new firms, $N_{E,t}$, minus the mass of firms which leaves the market, $N_{X,t}$. When denoting the time-dependent share of leaving firms with γ_t, the mass of exiting firms

[16] The entry decision in BGMa and BGMb is also based on a present value criterium. They assume firms to be homogeneous.

[17] This assumption is in line with BGMa, BGMb, and Ghironi and Melitz (2005) but contrasts with Bergin and Corsetti (2008) and Blanchard and Giavazzi (2003) who assume entry costs to be paid proportional to the production volume.

[18] In BGMa and BGMb firms are hit with a death shock with a constant probability. Consequently, their model does not endogenously determine firm exits at all.

[19] We assume that entry and exit costs are sunk costs which are paid by the owners – the households – in terms of the consumption good.

[20] Alternatively, one could interpret $f_X mc_{i,t}$ as the liquidation value of a firm implying that a firm exits the market if the present value of production is smaller than the liquidation value.

is given by $N_{X,t} = \gamma_t N_{t-1}$. By assumption, there exists a constant set of potential entrants, $N^{\max}$, which enter the market, if their respective entry is profitable, such that $N_{E,t} = \phi_{t-1}(N^{\max} - N_{t-1})$ where ϕ_t denotes the share of entering firms. We implement a time-to-build lag to capture the empirical finding of the lagged firm creation [see Figure 3.3].[21]

The mass of producing firms in the market then follows[22]

$$N_t = \phi_{t-1}N^{\max} + N_{t-1}(1 - \phi_{t-1} - \gamma_t) \tag{3.11}$$

More precisely, the shares of entering and exiting producers are given by

$$\phi_t = 1 - \Gamma(\delta_t^{in}), \quad \gamma_t = \Gamma(\delta_t^{out}) \tag{3.12}$$

where Γ is the CDF of the individual productivity level. (3.12) implies that on the one hand all non-producing firms with an individual productivity which is above the threshold, δ_t^{in}, will enter the market since their net present value of entering is at least non-negative. On the other hand, all existing firms with an individual productivity below the threshold, δ_t^{out}, will consequently leave since their net present value of production is non-positive.

3.2.2 Aggregation

The price index, defined in (3.2), can be expressed in terms of the average producer price[23]

$$P_t = N_t^{\frac{1}{1-\zeta}} \widetilde{P}_t \quad \Leftrightarrow \quad \widetilde{\rho}_t = \frac{\widetilde{P}_t}{P_t} = N_t^{\frac{1}{\zeta-1}} \tag{3.13}$$

where $\widetilde{P}_t \equiv P_{i,t}(z_i = \widetilde{z})$. As in Melitz (2003), the average individual productivity level, $\widetilde{z}$, is based on a weight which is proportional to the relative output share of firms

$$\widetilde{z} \equiv \left[\int_{z_{min}}^{\infty} z_i^{\zeta-1} g(z_i) dz_i\right]^{\frac{1}{\zeta-1}} \tag{3.14}$$

where $g(\cdot)$ is the PDF of the Pareto distribution.

Hence, the real price of the average intermediate good, $\widetilde{\rho}_t$, is a function of product variety, as it ceteris paribus increases in the mass of firms. This also holds for aggregate production which is given by[24]

$$Y_t = N_t^{\frac{\zeta}{\zeta-1}} \widetilde{y}_t \tag{3.15}$$

[21] An equivalent assumption can also be found in Bergin and Corsetti (2008), Bilbiie, Ghironi, and Melitz (2007a, 2007b), and Ghironi and Melitz (2005).

[22] An equivalent law of motion is applied in Lechthaler, Merkl, and Snower (2010) and Faia, Lechthaler, and Merkl (2010a) for employment dynamics.

[23] See the Appendix for a proof. There we solve the integral defined in (3.4). Hence, equation (3.13) represents an exact solution and not an approximation via average values.

[24] Equation (3.15) directly follows from (3.13). See the Appendix for a proof.

where $\widetilde{y}_t \equiv y_{i,t}(z_i = \widetilde{z})$. As in Bergin and Corsetti (2008), a rising mass of firms thus causes ceteris paribus the aggregate level of output to increase.

The aggregated production function consequently follows

$$Y_t = A_t \widetilde{z} N_t^{\frac{1}{\zeta-1}} L_t \tag{3.16}$$

where total hours worked, L_t, is given by $N_t \widetilde{l}_t$ with $\widetilde{l}_t \equiv l_{i,t}(\widetilde{z})$. The total factor productivity, TFP, defined as Y_t/L_t, is thus not only a function of productivity but also of the mass of producers

$$TFP_t = A_t \widetilde{z} N_t^{\frac{1}{\zeta-1}} \tag{3.17}$$

According to (3.13), the change in the average individual price level, $\widetilde{\pi}_t$, i.e. producer price index (PPI) inflation, can be expressed as

$$\widetilde{\pi}_t = \pi_t \left(\frac{N_t}{N_{t-1}} \right)^{\frac{1}{\zeta-1}} \tag{3.18}$$

Note that in general the two inflation rates only coincide in the steady state.[25]

3.2.3 Households

In opposition to firms, households are homogeneous. They supply their labor force to all kinds of producing firms.

Since firms decide to leave the market before they start producing, i.e. before they have a need for input factors, households do not supply labor to exiting firms. The probability of exiting the market can thus be neglected in the decision process of the household. Without loss of generality, we moreover assume the representative household to be faced with a mutual fund that pays dividends equal to total profits, Ψ_t, instead of being faced with the mass of heterogeneous single firms.[26] Writing the problem in terms of share holdings in individual firms would complicate the notation and ultimately result in identical equilibrium conditions [see Ghironi and Melitz (2005)].

The representative household maximizes its expected utility life-time value given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\chi}{1+\eta} L_t^{1+\eta} \right) \tag{3.19}$$

subjected to its budget constraint which in real terms follows

$$C_t + \frac{B_t}{P_t} = \frac{R_{t-1}}{P_t} B_{t-1} + w_t L_t + \Psi_t + T_t \tag{3.20}$$

[25] Since the mass of firms is pre-determined – implying a smooth adjustment pattern – and $\zeta > 1$, the absolute difference between π_t and $\widetilde{\pi}_t$ is very small. Our simulations in Section 3.4 verify this result.

[26] As in the baseline New Keynesian model, Ψ_t, is thus exogenous for the optimization problem of the household.

where C_t, L_t, B_t, and T_t respectively represent the household's real consumption expenditure, the labor supply, bonds holdings, and received transfers in period t. R_t is the gross nominal interest rate. The inverse of the intertemporal elasticity of substitution and the inverse of the Frisch elasticity of labor supply are represented by σ and η, respectively. R_t denotes the gross nominal interest rate. $\beta \in (0,1)$ is a discount factor and $\chi > 0$.

The following optimality conditions hold

$$w_t = \chi L_t^{\eta} C_t^{\sigma} \tag{3.21}$$

$$C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} \frac{R_t}{\pi_{t+1}} \right\} \tag{3.22}$$

3.2.4 Overall Resource Constraint

The resource constraint of the government is given by

$$P_t G_t = B_t - R_{t-1} B_{t-1} - P_t T_t \tag{3.23}$$

where G_t is government expenditure.

Inserting (3.23) in the household's resource constraint (3.20) yields

$$C_t + G_t = w_t L_t + \Psi_t \tag{3.24}$$

Aggregate per period profits are given by

$$\Psi_t = N_t \left[\widetilde{\rho}_t \widetilde{y}_t - w_t \widetilde{l}_t - \phi_{t-1} f_E \widetilde{mc}_t \right] - \frac{\theta^c}{2} (\pi_t - \overline{\pi})^2 Y_t - N_{X,t} f_X \widetilde{mc}_t \tag{3.25}$$

i.e. aggregate average profits from production minus entering cost minus adjustment costs of the wholesale sector and exiting costs. Inserting (3.15) and (3.13) in (3.25) yields

$$\begin{aligned}
\Psi_t &= N_t \underbrace{N_t^{\frac{1}{\varsigma-1}}}_{\widetilde{\rho}_t} \underbrace{N_t^{\frac{\varsigma}{1-\varsigma}} Y_t}_{\widetilde{y}_t} - w_t \underbrace{N_t \widetilde{l}_t}_{L_t} - \frac{\theta^c}{2} (\pi_t - \overline{\pi})^2 Y_t - N_t \phi_{t-1} f_E \widetilde{mc}_t - \underbrace{N_{X,t}}_{N_t \gamma_t} f_X \widetilde{mc}_t \\
&= Y_t - w_t N_t - \frac{\theta^c}{2} (\pi_t - \overline{\pi})^2 Y_t - N_t \phi_{t-1} f_E \widetilde{mc}_t - N_t \gamma_t f_X \widetilde{mc}_t
\end{aligned} \tag{3.26}$$

By inserting (3.26) in (3.24), we finally obtain the overall resource constraint[27]

$$C_t = Y_t - G_t - \frac{\theta^c}{2} (\pi_t - \overline{\pi})^2 Y_t - N_t \widetilde{mc}_t (f_E \phi_{t-1} + f_X \gamma_t) \tag{3.27}$$

[27] Remark: In contrast to the previous chapter, we assume that entry and exit costs are paid in terms of the consumption good. Consequently, they are a component of goods demand. We thus do not have to distinguish between output and GDP in this framework. Hence, we will use the terms output and GDP synonymously in the following.

3.2.5 Monetary Policy and Endogenous Trade-Off

In contrast to BGMb, our model generates an endogenous trade-off for monetary policy by endogenizing firm entry and exit. To show that, we aggregate and log-linearize the Phillips curve (3.6) and insert equation (3.13).[28]

$$\widehat{\widetilde{\pi}}_t = \beta \widehat{\widetilde{\pi}}_{t+1} + \frac{\zeta - 1}{\theta^c} \widehat{mc}_t - \frac{1}{\theta^c} \widehat{N}_t \tag{3.28}$$

For the threshold δ_t^{in}, (3.9) holds with equality. Log-linearizing this equation yields[29]

$$\widehat{mc}_t = \widehat{\delta}_t^{in} + \frac{\Psi}{f_E \frac{\widetilde{mc}}{\delta^{in}}} \left[\widehat{w}_t + \widehat{l}_t + \beta E_t \widehat{\Psi}_{t+1} + \beta\sigma(\widehat{C}_t - E_t \widehat{C}_{t+1}) \right] \tag{3.29}$$

It directly follows from (3.28) and (3.29) that the threshold for the entry decision, $\widehat{\delta}_t^{in}$, acts as an *endogenous* cost push shock and thus generates an endogenous trade-off for monetary policy between the stabilization of output and inflation.[30] If the threshold for an entry increases, the endogenous cost push shock leads to an increase in the marginal costs. This result is analogous to models concerning labor turnover costs, where the introduction of hiring/firing costs generates a similar cost push shock [see Faia, Lechthaler, and Merkl (2010a)].

There is however no attempt to derive the optimal monetary policy in this chapter. We leave that for future research. Instead, the monetary authority simply follows a standard Taylor rule. The endogenous cost-push shock has however important implication for the resulting dynamics.

The applied monetary policy rule in log-linear form is given by

$$\widehat{r}_t = \varrho \widehat{r}_{t-1} + (1 - \varrho)(\lambda_\pi \widehat{\pi}_t + \lambda_y \widehat{y}_t) + \kappa_t \tag{3.30}$$

where κ_t represents an AR(1) interest rate shock which follows

$$\kappa_t = \rho_\kappa \kappa_{t-1} + \varepsilon_t^\kappa \tag{3.31}$$

The complete model is shown in Table 3.1

3.3 Parameterizations

In the baseline calibration, we set the discount factor, β, to 0.99 which implies a steady state value of the annual interest rate of about 4%. As widely applied in the literature, the inverse of the elasticity of intertemporal substitution, σ, and

[28] In the following, a hat denotes a variable which is log-linearized around the corresponding zero inflation steady state, i.e. $\widehat{x}_t = \frac{X_t - X}{X}$. Variables without time index are steady state values.

[29] See the Appendix for a proof.

[30] Naturally, the same holds true for the threshold for exiting.

$$
\begin{aligned}
&Y_t = N_t^{\frac{\zeta}{\zeta-1}} \widetilde{y}_t \\
&Y_t = A_t \widetilde{z} N_t^{\frac{1}{\zeta-1}} L_t \\
&\widetilde{\pi}_t = \pi_t \left(\frac{N_t}{N_{t-1}} \right)^{\frac{1}{\zeta-1}} \\
&w_t = \chi L_t^{\eta} C_t^{\sigma} \\
&C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} \frac{R_t}{\pi_{t+1}} \right\} \\
&Y_t = C_t + G_t + \frac{\theta^c}{2} (\pi_t - \overline{\pi})^2 Y_t + N_t \widetilde{mc}_t (f_E \phi_{t-1} + f_X \gamma_t) \\
&\widetilde{\rho}_t = \frac{\zeta}{\zeta-1} \widetilde{mc}_t - \frac{\theta^c}{\zeta-1} \left[(\widetilde{\pi}_t - \overline{\pi}) \widetilde{\pi}_t - E_t \left\{ \Delta_{t,t+1} (\widetilde{\pi}_{t+1} - \overline{\pi}) \widetilde{\pi}_{t+1} \frac{\widetilde{y}_{t+1}}{\widetilde{y}_t} \right\} \right] + \frac{\zeta}{\zeta-1} \frac{\theta^c}{2} (\widetilde{\pi}_t - \overline{\pi})^2 \\
&\widetilde{mc}_t = \frac{w_t}{A_t \widetilde{z}} \\
&N_t = \phi_{t-1} N^{\max} + N_{t-1} (1 - \phi_{t-1} - \gamma_t) \\
&\phi_t = 1 - \Gamma(\delta_t^{in}), \quad \gamma_t = \Gamma(\delta_t^{out}) \\
&\widetilde{\rho}_t = N_t^{\frac{1}{\zeta-1}} \\
&f_E mc_t(\delta_t^{in}) = \frac{1}{\zeta-1} w_t l_t + E_t \{ \Delta_{t,t+1} \Psi_{t+1} \} \\
&f_E mc_t(\delta_t^{out}) = \frac{1}{\zeta-1} w_t l_t + E_t \{ \Delta_{t,t+1} \Psi_{t+1} \} \\
&\frac{R_t}{\overline{R}} = \left(\frac{\pi_t}{\overline{\pi}} \right)^{\lambda_\pi} \left(\frac{Y_t}{\overline{Y}} \right)^{\lambda_y} \exp\{\kappa_t\} \\
&L_t = N_t l_t \\
&mc_t(\delta_t^{in}) = \widetilde{mc}_t \frac{\widetilde{z}}{\delta_t^{in}} \\
&mc_t(\delta_t^{out}) = \widetilde{mc}_t \frac{\widetilde{z}}{\delta_t^{out}} \\
&E_t \Delta_{t,t+1} = \beta \left(\frac{E_t C_{t+1}}{C_t} \right)^{-\sigma}
\end{aligned}
$$

Table 3.1: *The complete New Keynesian model with endogenous firm entry and exit*

the Frisch elasticity of labor supply, η, are respectively set to 1 and 2.[31] Following BGMa, BGMb, and Ghironi and Melitz (2005) the price elasticity of the demand for the intermediate good, ζ, is assumed to be equal to 3.8 which is a rather small value.[32] However, we want to remain as close as possible to the calibration of BGMb. Therefore, we also set θ^c to 77 as estimated by Ireland (2001) in order to obtain the same slope of the Phillips curve as in BGMb. We moreover abstract from trend inflation, i.e. $\overline{\pi} = 1$.

For calibrating the first scaling parameter of the Pareto distribution, k, it is important that the condition $k > \zeta - 1$ holds in order to ensure the standard deviation of the idiosyncratic shock to be finite and positive [see Ghironi and Melitz (2005)].[33]

[31] In contrast to Chapter 2, we set η to 2 which is also a standard value in this chapter. The influence of this parameter will be shown in Section 3.4.1.

[32] In Section 3.6, we estimate the CPI-Phillips curve. It turns out that ζ has to be significantly higher than we assume here.

[33] Remark: The standard deviation of the Pareto distributed individual productivity level is given by $(k - \zeta +$

Therefore, k is calibrated to 3.4 as in Ghironi and Melitz (2005). To be able to compare our results with models without heterogeneity, the second scaling parameter, $z_{\min}$, is chosen to obtain an average individual productivity level equal to one. The exogenous government spending/GDP ratio in steady state, G/Y, is calibrated at a 18% level as in Smets and Wouters (2007). Moreover, we set the steady state values of the probability of exiting and entering, ϕ and γ, both equal to 0.025 implying an average annual firms' birth and death rate of 10% which is consistent with US economy data.[34] Without loss of generality, we normalize the mass of potential firms $N^{\max}$ to 100%. The proportionality constants of the entry and exit costs, f_E and f_X, are endogenously determined by the steady state system. It turns out that entry costs are about twice as large as exit costs which seems to be plausible.[35] In particular, this implies that a potential firm needs a higher individual productivity level for a profitable entry than an existing firm for staying in the market. As a consequence, producing firms are protected by barriers to entry.

The Taylor rule is calibrated in the standard fashion, i.e. λ_π and λ_y are set to 1.5 and 0.125, respectively. Finally, the smoothing parameter, ϱ, is set to zero in the baseline calibration.

The shocks to aggregate productivity, to government spending, and to the interest rate follow an AR(1) process: $x_t = \rho_x x_{t-1} + \varepsilon_t^x$ with $x = \{a, g, \kappa\}$. We calibrate these processes to the estimated values of Smets and Wouters (2007). Hence, the corresponding autocorrelation coefficients (ρ_a, ρ_g, and ρ_κ) are respectively 0.95, 0.97, and 0.15 whereas the standard errors are 0.45, 0.53, and 0.24.

3.4 Impulse Responses

In the following, we will discuss the described shocks to aggregate technology, to government spending, and to the interest rate. To deliver comparable results with BGMb, we will first present the results of our model for each shock when assuming exits to be exogenous. For this model specification, we simply set the exit rate equal to its calibrated constant steady state value, i.e. $\gamma_t = \gamma$. Then a constant fraction of firms exits the market before it starts production. It turns out that due to heterogeneity and due to the different entry mechanism,[36] our approach performs better than BGMb in some important aspects even in this simplified specification. Second, we show when endogenizing firm exit the model generates an additional amplification effect.

$1)^{-1}$.

[34] Industry level data for the US economy is provided by the US Small Business Administration (SBA) and available at http://www.sba.gov/advo/stats/dyn_ us_ 89_ 98s4.txt

[35] The numerical evaluation of f_E and f_X yields approximately 2.12 and 1.24, respectively.

[36] In contrast to BGMb, we do *not* assume firms to be homogenous. Instead, we assume firms – producing *and* potential ones – to be heterogeneous. The heterogenous individual productivity level is then crucial for evaluating the profitability of entering and exiting the market.

3.4.1 Overall Productivity Shock

Figure 3.5 shows the impulse responses[37] to the persistent shock to aggregate technology when firm exits are assumed to be exogenous. As expected and in line with numerous empirical analyses, the shock causes aggregate output and consumption to increase while (PPI and CPI) inflation decreases.

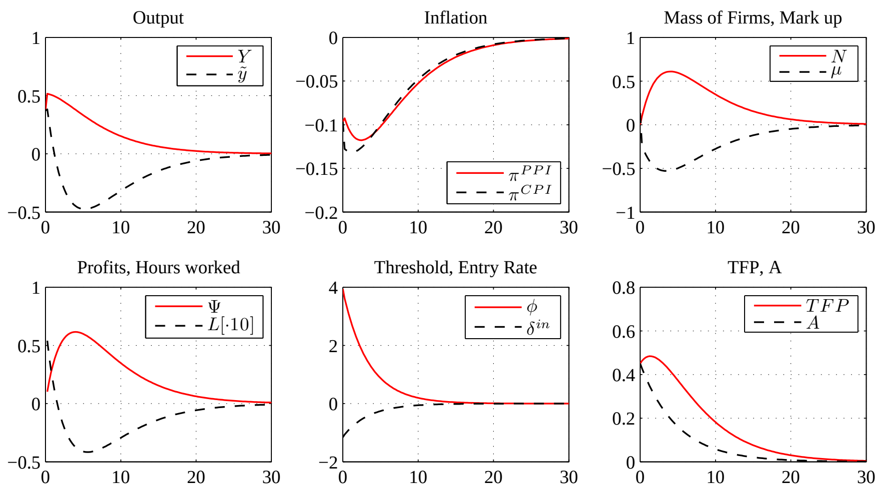

Figure 3.5: *Impulse responses to a persistent shock to aggregate productivity with exogenous exits*

As in BGMa and BGMb, the production volume of the average firm however increases only on impact. Thereafter, the reaction turns negative. The economic interpretation is that although the aggregate productivity shock has a positive effect on the production level of the individual firm, this effect is compensated by a decreasing market share. As higher productivity leads to higher profit opportunities – which causes the threshold for entering the market to decrease – the probability of entering increases. Hence, our model depicts the empirically observed pro-cyclical movement of firm entry [cf. Figure 3.1]. The rising mass of producing firms in turn causes the market share of the individual firm – defined as $\widetilde{y}_t/Y_t$ – per se to decrease.[38] In contrast to BGMb, the adjustment time-path of the mass of producers and GDP

[37] We simulate the model in log-linear form using Dynare V.4. The complete model in log-linear form is shown in the Appendix. The number of years are on the abscissa. However, we interpret periods as quarters. On the ordinate we plot the percentage deviation of a variable from the corresponding steady state value, i.e. $x_t = (X_t - \overline{X})/\overline{X}$, where $\overline{X}$ is the steady state value.

[38] Remark: According to (3.15) the ratio $\widetilde{y}_t/Y_t$ is given by

$$\frac{\widetilde{y}_t}{Y_t} = \frac{\widetilde{y}_t}{N_t^{\frac{\zeta}{\zeta-1}}\widetilde{y}_t} = N_t^{-\frac{\zeta}{\zeta-1}}$$

Log-linearizing this expression yields $\widehat{y}_t - \widehat{Y}_t = -\frac{\zeta}{\zeta-1}\widehat{N}_t$ such that the resulting dynamics look qualitatively equivalent to those of the mass of firms with inverse sign. They are thus hump-shaped and negative over the total adjustment path.

are both hump-shaped.

Moreover, Figure 3.5 indicates that as in BGMa and BGMb the shock impact is amplified by assuming an endogenous mass of firms since total factor productivity, TFP, increases more than aggregate productivity. This directly follows from equation (3.17) as the mass of producers rises. This result is also obtained by Jaimovich and Floetotto (2008) who show that TFP is a decreasing function in the firms' mark-up in their approach.[39] This finding is moreover analogous to the results of Bergin and Corsetti (2008) and Totzek and Winkler (2010) who show that an increasing mass of firms leads to an amplification effect in the case of an expansionary shock to monetary and fiscal policy, respectively. In line with the empirical findings of Galí, Gertler, and López-Salido (2007), Martins, Scapetta, and Pilat (1996), and Rotemberg and Woodford (1991, 1999), our model is also able to generate counter-cyclical mark-up movements without implying counter-cyclical profits.[40] Note however that these mark-up movements result from the assumption of sticky prices.

When comparing the impulse responses to those of BGMb, it turns out that beside the dynamics of inflation our model behaves qualitatively equivalent. However, BGMb show that an expansionary shock to aggregate technology can lead to a positive reaction of inflation depending on the degree of shock persistence in their model [see also Lewis (2009b)]. Lewis (2006) moreover shows that the entry model of BGMb causes inflation only to decrease on impact. Thereafter, the reaction is positive for degrees of shock persistence between 0.6 and 0.99. A positive reaction of inflation however conflicts with the empirical insights of e.g. Dedola and Neri (2007), Galí and Rabanal (2004), Smets and Wouters (2003, 2007), and Lewis (2009b, 2006). As Figure 3.6 depicts, our model generates a completely negative reaction of inflation independently of the persistence coefficient, ρ_a. It even generates a decrease in inflation after a one-off shock to aggregate technology.

There are two opposing effects leading to an increase in inflation in BGMb. On the one hand, the real wage increases more than aggregate technology. As a result, marginal costs increase which has a positive impact on inflation according to the Phillips curve. The rising mass of producers on the other hand has a negative impact on inflation [cf. equation (3.28)]. The reaction of the mass of producers is however rather small in BGMb.[41] By contrast, our framework generates a stronger reaction of the mass of firms development. At the peak, the percentage deviation of the mass of firms from its steady state value is even above that of the technology shock. The increase in marginal costs is moreover dampened by the endogenous cost-push

[39] The mark-up then turns out to be a declining function of the mass of producers.

[40] This result is also obtained by Jaimovich and Floetotto (2008), BGMa, and BGMb in a framework with endogenous entry. See Ravn, Schmitt-Grohé, and Uribe (2006, 2008) for an alternative theoretical approach which also generates counter-cyclical mark-up movements by introducing 'deep habits'. Standard DSGE models, on the other hand, predict a positive correlation between mark-up and profit movements.

[41] An increase in aggregate technology by 1% leads to a maximum reaction of the mass of producers by about 0.5%.

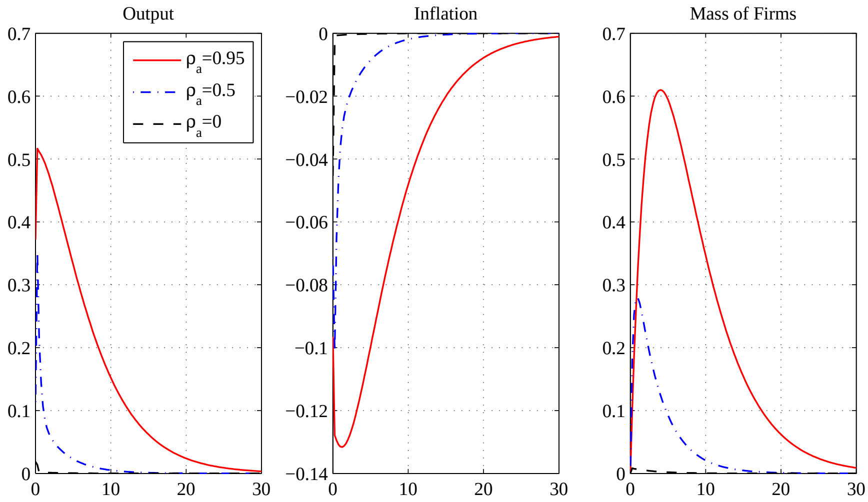

Figure 3.6: *Impulse responses to a shock to aggregate productivity with exogenous exits*

shock since the threshold for an entry decreases in our model [cf. equation (3.29)]. All in all, the effects leading to a decrease in inflation are much stronger in our framework causing a robust reaction of inflation independently of the degree of shock persistence.

There is a widespread agreement in the empirical literature that the correlation between productivity shocks and total hours worked is negative [see amongst others Francis and Ramey (2004, 2005), Galí and Rabanal (2004), and Galí (1999)].[42] Under our baseline calibration, total hours worked increase on impact. Thereafter, the reaction turns negative [see Figure 3.5]. However, the reaction of total hours worked is very sensitive to the calibration of the households' utility function in our framework. By decreasing the inverse of the intertemporal elasticity of substitution, σ, to 0.5, our model generates a totally expansionary reaction of total hours worked leaving the remaining variables qualitatively unchanged. Note that also a completely contractionary reaction of aggregate labor can be generated when setting $\sigma = 2$.

It is worthwhile to mention that an equivalent result can also be obtained in the RBC core of our model. We can thus contribute to the debate in the RBC literature initiated by Galí (1999), whether an overall technology shock leads to an expansionary or contractionary reaction of aggregate labor. To show that, we have to modify our framework. First, we do not assume prices to be sticky for this exercise. Second, we have to consider capital in our model. The production function is assumed to follow $y_{i,t} = A_t z_i l_{i,t}^{1-\alpha} k_{i,t}^{\alpha}$ with $\alpha = 0.3$ which is a standard value. The capital

[42] Note however that there also exists empirical support for the increase in aggregate labor, e.g. by Dedola and Neri (2007) who emphasizes a positive correlation between total hours worked and productivity in the US economy.

depreciation rate, δ^k, is set to 0.025.[43] This is a further advantage of our model since the framework of BGMa can only be extended by capital in product creation and production when considering a depreciation rate larger than 50%. Otherwise, the resulting impulse responses are oscillating and no longer plausible [see BGMa]. When varying the inverse of the intertemporal elasticity of consumption, the RBC core version of our model can depict both an increase and a decrease in total hours worked leaving other variables qualitatively unchanged. The corresponding impulse responses are depicted in Figure 3.7.

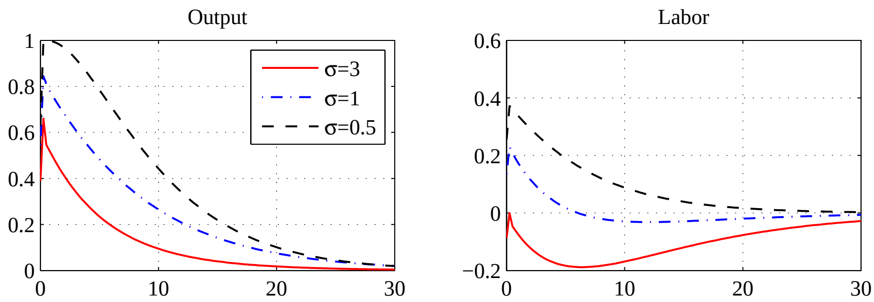

Figure 3.7: *The impact of the intertemporal elasticity of substitution on total hours worked in the RBC version*

We obtain a completely expansionary reaction of total hours worked in the case $\sigma = 0.5$, while our model generates a completely contractionary reaction when the inverse of the intertemporal elasticity of substitution is above 3. By contrast, standard RBC models always generate a positive co-movement between GDP and labor.[44]

The economic intuition for the qualitative change in the reaction of total hours worked is as follows. Independently of σ, the increasing real wage and the decreasing production volume of the single firm causes the labor demand of the average firm, $\widetilde{l}$, to decrease. However, total hours worked rise due to the expansionary reaction of the extensive margin. When decreasing the inverse of the intertemporal elasticity of substitution, present consumption is shifted into the future. The responses of consumption and GDP are thus dampened on impact. Due to the decreasing goods demand, the thresholds for entering increases. The expansionary reaction of the mass of firms is consequently dampened by raising the inverse of the intertemporal elasticity of substitution. As a result, total hours worked react contractionary since the effect resulting from the decline in individual labor demand becomes decisive if σ is sufficiently high.

Figure 3.8 shows impulse responses when firm entries and exits are both endoge-

[43] The complete RBC model considering capital is shown in the Appendix.

[44] As already mentioned, the sign of the reaction of hours worked crucially depends on the intertemporal elasticity of substitution within in a classical monetary model, i.e. in an RBC framework without capital[cf. Galí (2008, Ch.2)]. However, when considering capital in the model, hours worked always react expansionary [cf. Galí (1999)].

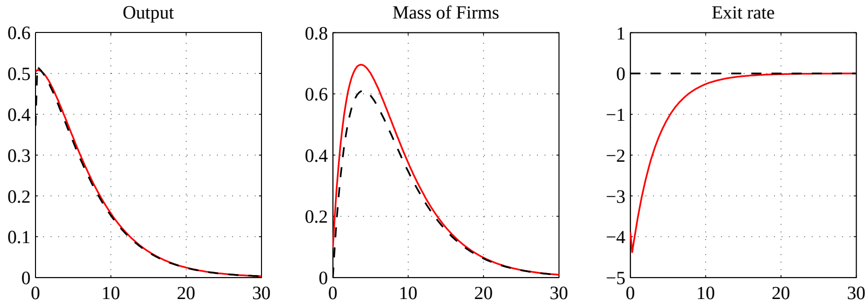

Figure 3.8: *Impulse responses to a persistent shock to aggregate productivity – endogenous [solid lines] vs. exogenous exits [dashed lines]*

nously determined via the incentive-based mechanism in comparison with the simplified model. As expected, the exit rate decreases after the expansionary technology shock. Our framework can thus depict the empirically observed counter-cyclical nature of exits [cf. Figure 3.2]. The decreasing exit rate additionally amplifies the development of the mass of producers. This in turn leads to a larger amplification effect on GDP leaving the qualitative reaction of other variables unchanged. However, the additional amplification in terms of output is rather small.

3.4.2 Government Spending Shock

Figure 3.9 depicts the impulse responses to an expansionary shock to government spending when firm exits are assumed to be exogenous.[45] As standard in New Keynesian and RBC models, private consumption crowds out due to the negative wealth effect.[46] The contractionary reaction of private consumption is dominated by the expansionary effect on government spending such that the aggregate goods demand increases.

Due to increasing profit opportunities, the threshold for an entry decreases. The extensive margin consequently reacts expansionary in a hump-shaped manner and amplifies the rise in (individual) output. During the remaining adjustment process, the reaction of individual output turns negative caused by the decreasing market share. This in turn leads to counter-cyclical mark-up movements without implying counter-cyclical profits.

As shown by Totzek and Winkler (2010), the reaction of the mass of firms caused by an increase in government consumption is not unambiguous in the entry model

[45] Note that BGMa and BGMb do not consider government spending in their analyses. In the following, we thus compare our results to Lewis (2009b) and Totzek and Winkler (2010) who extend the model of BGMb and BGMa to allow for government spending shocks, respectively.

[46] The wealth effect in New Keynesian and RBC models works as follows. Since the increase in government spending is financed by lump-sum taxation, it represents a negative effect on the total income of households. The households consequently decrease their consumption expenditures and increase their labor supply to compensate for the additional tax expenditures. This increase in labor supply in turn leads to an expansionary reaction of production [cf. Baxter and King (1993)].

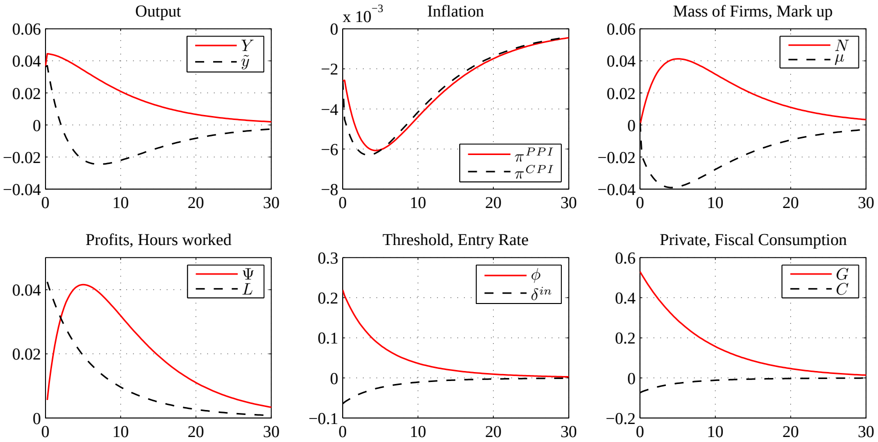

Figure 3.9: *Impulse responses to an expansionary shock to government spending (exogenous γ)*

of BGMa. Instead, the extensive margin only increases if the inverse of the Frisch elasticity of labor supply is low. For higher but commonly applied values of η, as for instance $\eta = 2$, the mass of firms decreases. A possible explanation for this development would be that the increasing profit opportunities caused by the fiscal stimulus are insufficient to cover the entry costs. The extensive margin then declines. However, a decreasing mass of producers caused by an expansionary demand shock conflicts with the intuition and the empirical results of Lewis (2009b). She shows that an expansionary shock to government spending causes a boom in firm entry.

In our framework, the reaction of the mass of producers is unambiguous. As shown in Figure 3.10, our model generates an expansionary reaction of the extensive margin for commonly applied values of the inverse of the Frisch elasticity of labor supply, $0.5 \leq \eta \leq 4$.[47] The impulse responses indicate that although the reaction of the mass of producers decreases in η, it remains strictly positive. Our approach is thus more robust with respect to this aspect when compared to the model of BGMa and BGMb.

The differences are caused by the assumption of heterogeneity across firms and the corresponding differences in the entry mechanism. Due to heterogeneity, there will always exist a firm with an individual productivity level which is only *slightly* below the threshold for a profitable entry.[48] This implies that even in the case of a small expansionary shock, an entry for this specific firm will be profitable and it will enter the market. As a consequence, the mass of producers increases. In the entry model of BGMb however, firms are homogeneous implying that small expansionary shocks do not have to cause firms to enter. Since the exit rate is assumed to be constant,

[47] Our model even generates an increase in the mass of firms for higher values of η.

[48] Note that this result would also hold for other distributions of the individual productivity level, e.g. a Normal or Student's t-distribution.

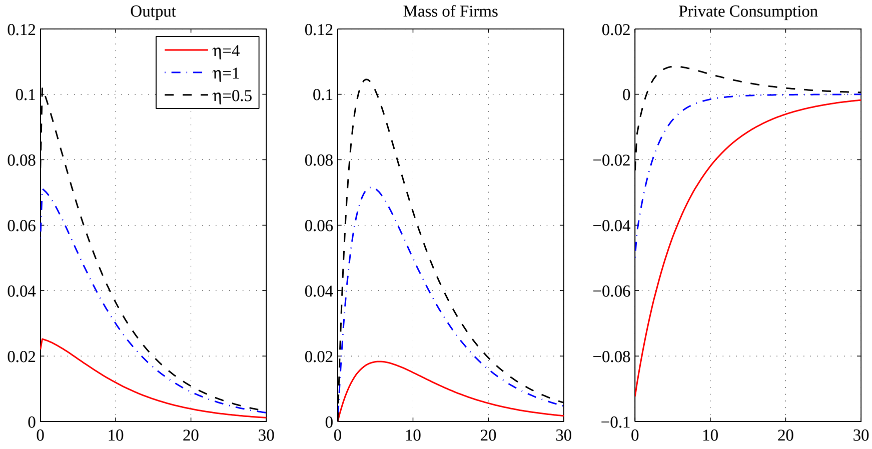

Figure 3.10: *Mass of firms development under different Frisch elasticities of labor supply (exogenous γ)*

the mass of firms declines, if entries do not react expansionary.

Figure 3.11 schematically depicts the differences in the entry decisions under heterogeneity and homogeneity. Under homogeneity all firms have the same productivity level. Under heterogeneity firms differ in their individual productivity level. Now, consider the following thought experiment and assume that there exists the same mass of firms in the initial position and that entry costs are constant in both scenarios. Since firms with a higher z_i are more productive, the profit opportunity function, PO, is increasing in z_i under heterogeneity, while it is constant under homogeneity across firms. Let us now assume that an expansionary shock hits the economy that increases the profit opportunities for all firms. As Figure 3.11 indicates, under *homogeneity* across firms, small expansionary shocks do *not* have to result in profitable entries, i.e. that the profit opportunities do not cover the entry costs. When however assuming *heterogeneity* across firms, also small shocks lead to profitable entries since there will always exist a firm with an individual productivity level which is slightly below δ_0^{in} in the initial position. In Figure 3.11, the shock causes firms with an individual productivity level $\delta_1^{in} \leq z_i < \delta_0^{in}$ to enter the market. Given a small shock, the mass of firms will consequently increase under heterogeneity, while it will not under homogeneity.

Moreover, Figure 3.10 shows that it is also possible to generate a positive reaction of private consumption in the longer-run in our framework. When assuming a larger Frisch elasticity of labor supply, i.e. a smaller η, the reaction of consumption turns positive.[49] The rationale is that by decreasing η, the reaction of labor supply is larger leading to a positive wealth effect. The reaction of the real interest rate consequently

[49]Naturally, the initial reaction always stays negative due to the negative wealth effect [see Baxter and King (1993)].

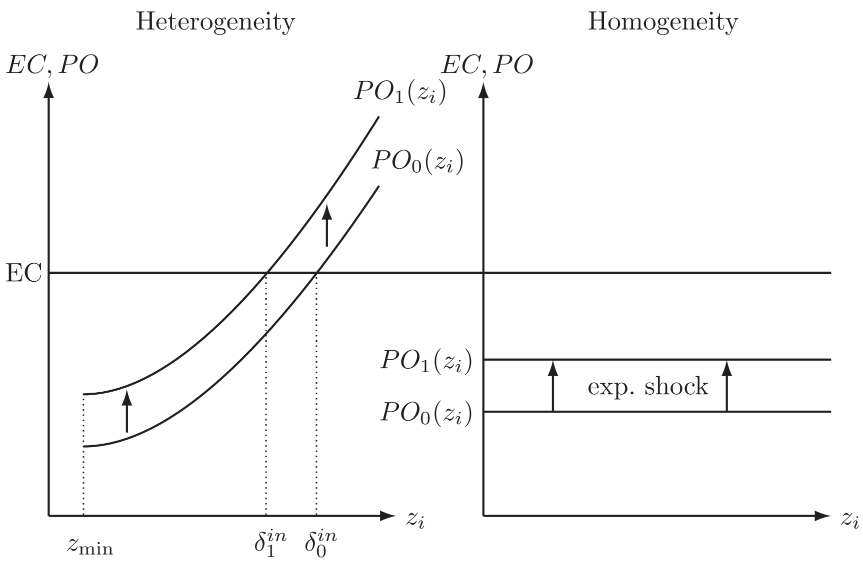

Figure 3.11: *Schematic illustration of entry decisions under heterogeneity and homogeneity [PO: profit opportunities, EC: entry costs]*

decreases and turns negative after some periods. This result also holds in the RBC specification of our model.

Another unsatisfactory feature of the entry model of BGMa and BGMb is that the mass of firms only increases for very high degrees of shock persistence [see Lewis (2009b) and Totzek and Winkler (2010)]. As shown by Totzek and Winkler (2010), a shock persistence of 0.9 is still too low to generate a boom in the extensive margin since the additional profit opportunities caused by the increase in government consumption are insufficient to cover the entry costs.

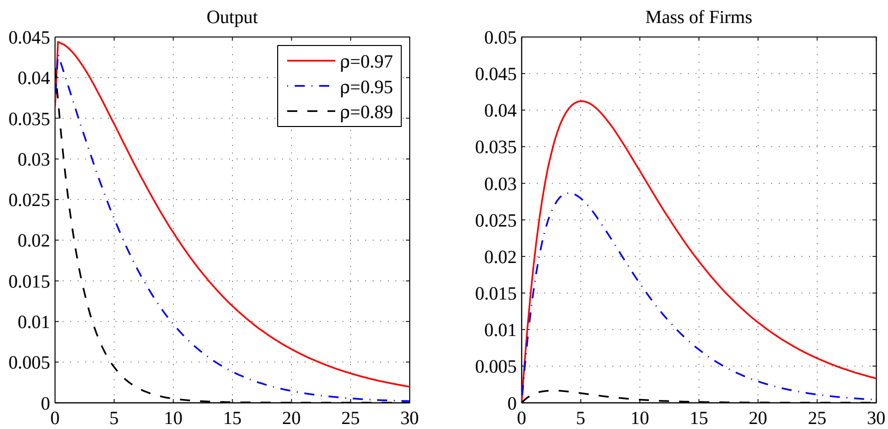

Figure 3.12: *Mass of firms development under different degrees of shock persistence (exogenous γ)*

The impulse responses depicted in Figure 3.12 indicate that our model is more robust with respect to this aspect, too, since it generates an increase in the mass of producers even for lower degrees of shock persistence.[50] This result is again caused by the assumption of firms' heterogeneity and the corresponding entry mechanism. As a result, also less persistent shocks cause a boom in the extensive margin.

As shown in Smets and Wouters (2003, 2007) and Lewis (2009b), inflation increases after a rise in government consumption which is at odds with the impulse responses depicted in Figure 3.9. However, Linnemann and Schabert (2003) show that the qualitative reaction of inflation crucially depends on the design of monetary policy in the baseline New Keynesian model. More precisely, the coefficient on output, λ_y, is the decisive factor. Figure 3.13 shows that this is also the case in our model. The reaction of inflation turns from completely negative to completely positive when decreasing the coefficient on output in the Taylor rule.

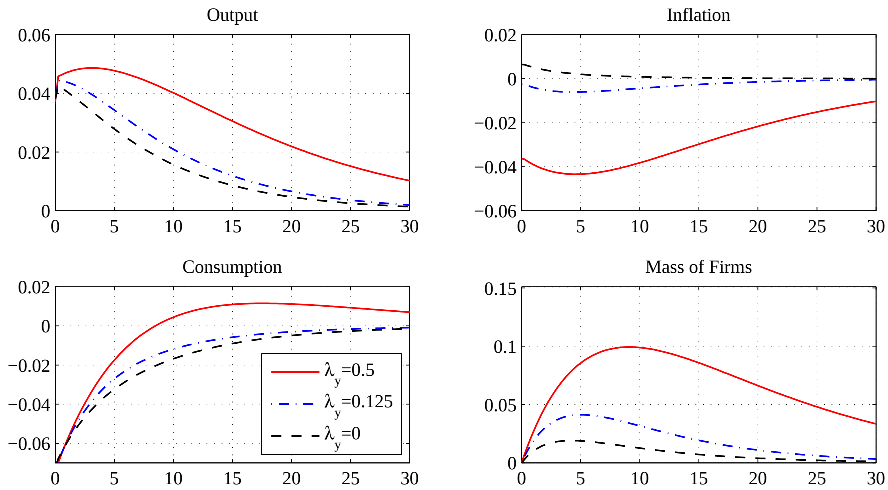

Figure 3.13: *Mass of firms development under different Taylor rule coefficients λ_y (exogenous γ)*

As in the baseline New Keynesian model, $\lambda_y > 0$ leads to a downward-pressure on the nominal interest rate.[51] This in turn leads to a higher goods demand. Figure 3.13 moreover shows that consumption can also react expansionary in the longer-run, if the monetary authority reacts to changes in output, too. The real interest rate then turns negative after some periods leading to an increase in private consumption. As a consequence, the increasing profit opportunities are larger compared to the case $\lambda_y = 0$ leading to larger reaction in the extensive margin and in GDP.

Also in the case of an expansionary shock to government spending, all results re-

[50] Note however that also in our model a contractionary reaction of the mass of producers is possible. This is the case if the shock persistence is below 0.88. When applying a Taylor rule with $\lambda_y = 0.5$, the mass of firms also increases for $\rho_a = 0.85$.

[51] The fiscal demand shock causes goods demand and thus inflation to increase. The monetary authority consequently increases the interest rate which ceteris paribus leads to a decline in current consumption. If $\lambda_y > 0$ this would dampen the rise in the interest rate. By contrast, this is not the case if $\lambda_y = 0$ [cf. Linnemann and Schabert (2003)].

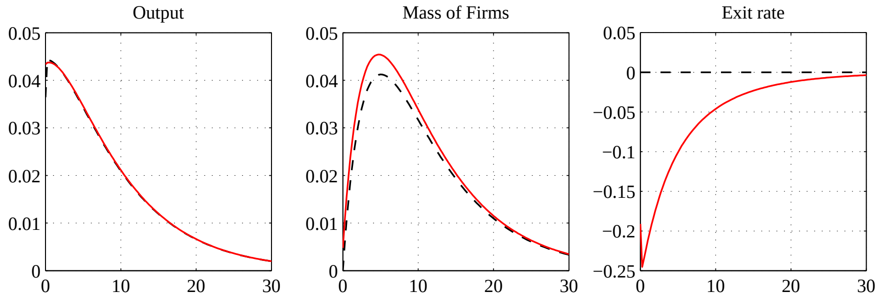

Figure 3.14: *Impulse responses to an expansionary shock to government spending – endogenous [solid lines] vs. exogenous exits [dashed lines]*

main qualitatively unchanged when endogenizing firm exit. The decreasing exit rate causes a stronger reaction of the extensive margin in comparison with the outcome under exogenous exits. As a result and as in the case of the expansionary technology shock, the model with endogenous exits generates a stronger amplification effect with respect to GDP. Figure 3.14 shows the corresponding impulse responses in comparison with the simplified model. However, the quantitative change in the development of output is even smaller than in the case of the technology shock [cf. Figure 3.8].

3.4.3 Interest Rate Shock

Since the shock to monetary policy is not assumed to be very persistent, we follow BGMb and apply a Taylor rule with interest rate smoothing to generate more persistent developments. The applied Taylor rule is given by: $r_t = 0.9r_{t-1} + (1 - 0.9)(1.5\pi_t + 0.5y_t) + \kappa_t$. Figure 3.15 shows the resulting impulse responses when firm exits are assumed to be exogenous.

The impulse responses of GDP, inflation, and total hours worked are in line with the empirical evidence of amongst others Smets and Wouters (2007, 2003). When comparing our results with BGMb, it turns out that beside the reaction of the extensive margin, our model also behaves qualitatively equivalent. However, our model generates an increase in the mass of producers whereas BGMb obtain the counter-intuitive result that an expansionary shock to monetary policy causes the mass of producers to decline. This result moreover conflicts with empirical insights of Bergin and Corsetti (2008) and Lewis (2009b). Their VAR analyses show that a rise in the interest rate discourages entry.[52]

The underlying intuition for the different quantitative reactions is as follows. There exist two opposing effects which determine the reaction of the extensive margin.

[52] Remark: Bergin and Corsetti (2008) however show the sign of the unconditional correlation between the federal funds rate and firm creation crucially depends on the chosen measure for firm creation. They find a positive (negative) correlation between new incorporations (net business formation) and the federal funds rate.

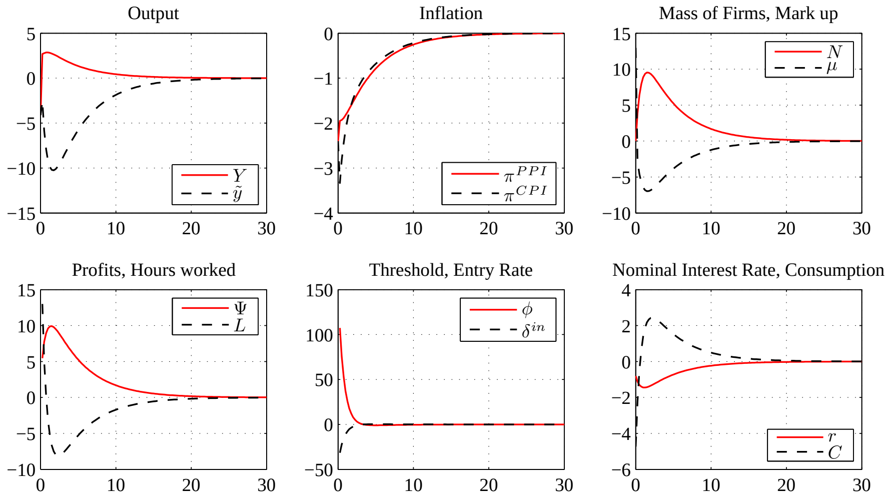

Figure 3.15: *Impulse responses to an expansionary shock to monetary policy (exogenous γ)*

(i) According to the Euler consumption equation, future consumption is shifted into the present when the interest rate falls. As a result, the expansionary reaction of goods demand leads to higher profit opportunities for producing and potential firms. (ii) The upward-pressure on marginal costs caused by a higher demand for labor results in an opposing negative effect on firm entry. In BGMb the second effect dominates the first since – as already mentioned – higher profit opportunities do not necessarily result in a positive effect on entry if entry costs are too high. As a result, the model of BGMb generates a decrease in the mass of firms which is at odds with the empirical evidence by Bergin and Corsetti (2008) and Lewis (2009b).[53] In our framework the first effect is stronger due to heterogeneity. Furthermore, the second effect is dampened by the endogenous cost-push shock which is expansionary in this case since the threshold for an entry decreases [cf. equation (3.29)]. All in all, the effects encouraging entry are stronger in our model leading to an increase in the mass of firms.

3.5 Second Moments

In this section, we evaluate our model by comparing the generated second moments with the empirical ones provided by King and Rebelo (1999). For this exercise, we first apply the RBC specification of our model with endogenous exits and compare

[53] Lewis (2009b) shows that by introducing wage stickiness to the model of BGMb, she can also generate an expansionary reaction of firm entry. However, her impulse responses are not hump-shaped as her VAR analysis indicates. Alternatively, Lewis (2009b) introduces an endogenous but ad hoc survival probability. In this case, net entry initially increases in a hump-shaped manner but then the reaction turns significantly negative.

the results with those obtained by BGMa. Second, we show that the introduction of sticky prices yields a further improvement since it intensifies our results. Third, we show that the assumption of exogenous exits leads to worse results.

We simulate the reaction of our model to an aggregate productivity shock 500 times for 400 quarters[54] and discard the first 200 quarters[55] to obtain the same sample size as in King and Rebelo (1999). We use the Hodrick-Prescott filter with a smoothing parameter of 10^5. In order to deliver comparable results with the data and BGMa, we calibrate the productivity shock process according to the empirically observed values of King and Rebelo (1999). We thus set the standard deviation, σ_a, and the autocorrelation coefficient, ρ_a, of the shock to 0.0072 and 0.979, respectively. For the exercise, we set ζ to 9 as estimated by Christiano, Eichenbaum, and Evans (2005).[56] The previously applied value of BGMa and BGMb ($\zeta = 3.8$) implies an empirically implausible mark-up of about 36%. In order to keep the k/ζ ratio constant, we also have to re-calibrate k to 8.05.[57] As standard in the literature, we further set α to 0.2. The rest of the parameters remains unchanged.

Table 3.2 shows the simulated second moments of our RBC model with endogenous firm entries and exits as log-deviations from the HP-trend in comparison to the empirically reported values (bold values) and the values obtained by BGMa (in parenthesis).[58] In contrast to BGMa, we do not introduce total investment as a new variable to the model. Instead, we will distinguish between investment in physical capital, I_t, and investment in new firms, $N_t\phi_{t-1}\Psi_t$. This has the advantage that we can have a closer look at the single components of investment.[59]

X	σ_X	σ_X/σ_Y	$E(X_tX_{t-1})$	$corr(X,Y)$
Y	**1.81** 1.43 (*1.40*)	**1.00**	**0.84** 0.70 (*0.70*)	**1.00**
C	**1.35** 1.21 (*0.57*)	**0.74** 0.85 (*0.41*)	**0.80** 0.74 (*0.65*)	**0.88** 0.77 (*0.99*)
L	**1.79** 1.40 (*0.97*)	**0.99** 0.98 (*0.69*)	**0.88** 0.71 (*0.71*)	**0.88** 0.53 (*0.99*)
I	**5.30** 1.82 (*3.33*)	**2.93** 1.27 (*2.38*)	**0.87** 0.69 (*0.73*)	**0.80** 0.73 (*1.00*)
$N\phi\Psi$	2.40	1.68	0.64	0.73

Table 3.2: *Second moments to an aggregate productivity shock [***data***,* RBC model, *(BGMa)]*

Table 3.2 shows that in contrast to BGMa our model performs better than standard

[54] In Chapter 2, we simulate 500 periods and then discard some periods to obtain the same sample size as in the data. However, this does not alter the results.

[55] King and Rebelo (1999) apply a data range of 1947:1-1996:4, i.e. 200 periods.

[56] More precisely, this is the estimated value for the RBC specification of their model.

[57] As already mentioned, it is important to generate a positive and finite standard deviation of the individual productivity level.

[58] More precisely, we compare our results with those of BGMa under a CES technology and capital in production. BGMa moreover provide the second moments for a model specification with capital in production as well as in firm creation. This specification would be the closest to our approach. However, this model specification has problems with indeterminacy and delivers implausible impulse responses if the capital depreciation rate is below 50% [cf. BGMa] which is at odds with the data. Therefore, we will compare our results with the model specification of BGMa with capital only in production.

[59] Note that King and Rebelo (1999) evaluate an RBC model. Therefore, they do not consider the inflation rate in their analysis.

RBC models. First, total hours worked and consumption do not react too smooth relative to output which is the case in BGMa. Instead, the relative standard deviation of total hours worked is very close to the empirically observed value and the relative standard deviation of consumption even slightly exceeds the empirically observed one. Second, the well-known problem of New Keynesian and RBC models – including BGMa and BGMb – that all variables behave too pro-cyclical vanishes, too. In BGMa the correlations between output and the other variables are approximately one.[60] In our model the generated values are even too low. With respect to the autocorrelations our model performs approximately equivalent to that of BGMa. Both models thus do not generate enough endogenous persistence. This is however another well-known problem of New Keynesian and RBC models.

When regarding the different types of investment, it turns out that investment in new firms is more volatile than investment in existing physical capital. Moreover, investment in new firms is less sticky, i.e. autocorrelated, than investment in physical capital which seems to be plausible.

For the next exercise, we assume sticky prices again. As in BGMb, we moreover assume the monetary authority to follow a Taylor rule with a higher weight on inflation ($\lambda_\pi = 3.5$), and a zero-weight on output ($\lambda_y = 0$). The generated second moments of our New Keynesian model are shown in Table 3.3 in comparison with those under flexible prices.

<table>
<tr><th>X</th><th colspan="3">σ_X</th><th colspan="3">σ_X/σ_Y</th><th colspan="3">$E(X_t X_{t-1})$</th><th colspan="3">$corr(X,Y)$</th></tr>
<tr><td>Y</td><td>1.81</td><td>1.37</td><td>(1.43)</td><td>1.00</td><td></td><td></td><td>0.84</td><td>0.71</td><td>(0.70)</td><td>1.00</td><td></td><td></td></tr>
<tr><td>C</td><td>1.35</td><td>1.14</td><td>(1.21)</td><td>0.74</td><td>0.82</td><td>(0.83)</td><td>0.80</td><td>0.74</td><td>(0.74)</td><td>0.88</td><td>0.77</td><td>(0.77)</td></tr>
<tr><td>L</td><td>1.79</td><td>1.75</td><td>(1.40)</td><td>0.99</td><td>1.28</td><td>(0.98)</td><td>0.88</td><td>0.68</td><td>(0.71)</td><td>0.88</td><td>0.57</td><td>(0.53)</td></tr>
<tr><td>I</td><td rowspan="2">5.30</td><td>1.81</td><td>(1.82)</td><td rowspan="2">2.93</td><td>1.30</td><td>(1.27)</td><td rowspan="2">0.87</td><td>0.70</td><td>(0.69)</td><td rowspan="2">0.80</td><td>0.75</td><td>(0.73)</td></tr>
<tr><td>$N\phi\Psi$</td><td>1.81</td><td>(2.40)</td><td>1.30</td><td>(1.68)</td><td>0.71</td><td>(0.64)</td><td>0.76</td><td>(0.73)</td></tr>
</table>

Table 3.3: *Second moments to an aggregate productivity shock [***data***, New Keynesian Model, (RBC model)]*

BGMb state that the introduction of sticky prices to the model does not change the results of the RBC version significantly since the outcomes of both models are virtually indistinguishable. However, this does not hold in our framework. By introducing sticky prices to our model, all previously obtained results become even stronger. The relative standard deviations of both consumption and labor now exceed the empirically observed such that both economic indicators do not react too smooth relative to output.[61] The absolute standard deviation of L_t is moreover very close to the empirically observed one.

[60] In the specification with capital in production as well as in firm creation BGMa obtain slightly lower values under the empirically implausible calibration. However, they are still above the empirically observed ones.

[61] This implies that the generated standard deviations of total hours worked and consumption in our framework are not too small in relation to the standard deviation of GDP as in standard RBC and New Keynesian models [cf. King and Rebelo (1999)].

As before, all variables do not react too pro-cyclical as it is the case in standard New Keynesian and RBC models [cf. King and Rebelo (1999)]. The cross-correlations between the variables and GDP only increase marginally in comparison with our RBC framework. In the New Keynesian specification the two types of investment nearly perform identical.

<table>
<tr><th>X</th><th colspan="3">σ_X</th><th colspan="3">σ_X/σ_Y</th><th colspan="3">$E(X_t X_{t-1})$</th><th colspan="3">$corr(X,Y)$</th></tr>
<tr><td>Y</td><td>1.81</td><td>1.38</td><td>(1.37)</td><td>1.00</td><td></td><td></td><td>0.84</td><td>0.71</td><td>(0.71)</td><td>1.00</td><td></td><td></td></tr>
<tr><td>C</td><td>1.35</td><td>1.08</td><td>(1.14)</td><td>0.74</td><td>0.78</td><td>(0.82)</td><td>0.80</td><td>0.75</td><td>(0.74)</td><td>0.88</td><td>0.72</td><td>(0.77)</td></tr>
<tr><td>L</td><td>1.79</td><td>1.04</td><td>(1.75)</td><td>0.99</td><td>0.75</td><td>(1.28)</td><td>0.88</td><td>0.69</td><td>(0.68)</td><td>0.88</td><td>0.69</td><td>(0.57)</td></tr>
<tr><td>I</td><td rowspan="2">5.30</td><td>1.73</td><td>(1.81)</td><td rowspan="2">2.93</td><td>1.25</td><td>(1.30)</td><td rowspan="2">0.87</td><td>0.54</td><td>(0.70)</td><td rowspan="2">0.80</td><td>0.71</td><td>(0.75)</td></tr>
<tr><td>$N\phi\Psi$</td><td>1.83</td><td>(1.81)</td><td>1.33</td><td>(1.30)</td><td>0.44</td><td>(0.71)</td><td>0.69</td><td>(0.76)</td></tr>
</table>

Table 3.4: *Second moments to an aggregate productivity shock [* **data**, New Keynesian Model with exogenous exits, *(New Keynesian Model with endogenous exits)]*

Table 3.4 shows the second moments for the New Keynesian specification of our model when assuming endogenous entries and exogenous exits. It shows that the simplified model can also generate a relative standard deviation of consumption which is slightly above the empirically observed value. However, this does not hold for total hours worked. In contrast to the model specification with endogenous exits and in line with standard New Keynesian models, total hours worked react too smooth relative to output. With respect to the autocorrelations the simplifying assumption of exogenous exits do not change the results significantly. Both model specifications do not generate enough endogenous persistence. Moreover, the autocorrelations of the two types of investment are rather small when exits are assumed to be exogenous. As in the RBC specification with endogenous exits, we obtain the unsatisfactory result that investment in new firms is more volatile than investment in physical (existing) capital. The result that the cross-correlations between the variables and GDP are smaller than the empirically observed values is additionally amplified by the assumption of exogenous exits.

All in all, the New Keynesian specification of our model with endogenous exits delivers the best results with respect to the second moments.

3.6 An Empirical Exercise

Since in our framework – as well as in BGMb – the Phillips curve occurs with an additional term depending on the development of the extensive margin, the question arises whether this term is significant at all [cf. Midrigan (2007)]. For quantifying the importance of this additional driving force in the inflation equation, we will estimate the log-linearized Phillips curve with the generalized method of moments (GMM) as in Galí and Gertler (1999) in this section.

Inserting the aggregate expression for the marginal costs as well as the aggregated production function (3.16) in the PPI Phillips curve (3.6) and log-linearizing yields

$$\widehat{\tilde{\pi}}_t = \beta E_t \widehat{\tilde{\pi}}_{t+1} + \underbrace{\frac{\zeta - 1}{\theta^c}}_{\omega} \widehat{S}_t \tag{3.32}$$

where $\widehat{S}_t \equiv \widehat{w}_t + \widehat{L}_t - \widehat{Y}_t$ is the labor share of national income.[62] ω represents the reduced form slope coefficient of the Phillips curve. Equation (3.32) represents a standard Phillips curve just depending on expected future inflation and the labor share. Hence, the mass of producers does not effect PPI inflation in our approach. This result is supported by US economy data since we do not find any significant correlation between PPI inflation and the extensive margin.[63]

However, by inserting the log-linearized version of (3.18) in (3.32), we obtain the CPI Phillips curve

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \frac{\zeta - 1}{\theta^c} \widehat{S}_t + \frac{1}{\zeta - 1} \left[\beta E_t \Delta \widehat{N}_{t+1} - \Delta \widehat{N}_t \right] \tag{3.33}$$

where $\Delta \widehat{N}_t \equiv \widehat{N}_t - \widehat{N}_{t-1}$. Hence, the change in the mass of producers occurs additionally to the labor share in the CPI Phillips curve (3.33). When regarding US economy data, it moreover turns out that the cross-correlation between CPI inflation and the change in the mass of firms is -0.13 and significant at a 95% level. This finding indicates that the development of the mass of firms affects CPI inflation.

For our estimations, we follow Galí and Gertler (1999) by using quarterly data for the US economy over the period 1960Q1:1997Q4.[64] The instrument set includes four lags of the output gap, the long-short interest rate spread, wage inflation, commodity price inflation, the non-farm labor's share, and overall GDP deflator inflation. Additionally, we take the data for the extensive margin seasonally adjusted and de-trended by application of the HP-filter. The data is constructed from new incorporations and firms' failures which are provided by the "Survey of Current Business" and the "Economic Report of the President" by the Council of Economic Advisors. Following Galí and Gertler (1999), we use a 12-lag Newey-West estimate of the covariance matrix.

In order to generate a benchmark, we first estimate the *standard* Phillips curve[65] with Calvo pricing where the marginal costs can be approximated by the labor share

[62] Note however that due to firm entry $\widehat{mc}_t \neq \widehat{S}_t$. See the Appendix for a proof.

[63] The applied data set is described below.

[64] The data of the extensive margin is just capable for 1959Q3:1998Q3. We thus do not loose many observations by applying the data range of Galí and Gertler (1999).

[65] In standard New Keynesian model, PPI and CPI inflation coincide.

[see Galí and Gertler (1999)].[66] It is given by

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \underbrace{\frac{(1-\vartheta)(1-\beta\vartheta)}{\vartheta}}_{\omega'} \widehat{S}_t \tag{3.34}$$

where $\vartheta \in (0,1)$ represents the Calvo parameter. ω' is the resulting reduced form slope parameter. Note that in contrast to Galí and Gertler (1999) but for the sake of comparability, we take the CPI for generating inflation for this exercise.[67] Under rational expectations the corresponding orthogonality condition[68] is given by

$$E_t \left\{ (\widehat{\pi}_t - \beta\widehat{\pi}_{t+1} - \omega' \widehat{S}_t)\Lambda_t \right\} = 0 \quad \left[\in \Re^{\Xi}\right] \tag{3.35}$$

where $\Lambda_t \in \Re^{\Xi}$ is the column vector of instruments and Ξ is the number of instruments. All instruments are observable at time t.

In the following an asterisk indicates significance at a 99% level. The estimation of (3.35) in reduced form yields

$$\widehat{\pi}_t = 0.9814^* E_t \widehat{\pi}_{t+1} + 0.2062^* \widehat{S}_t \tag{3.36}$$

Both estimates are significant and reasonable. As already shown by Galí and Gertler (1999), current inflation is significantly affected by the labor share beside expected future inflation, as the theoretical literature suggests.

The corresponding structural estimation of (3.35) using a nonlinear instrumental variables estimator yields a discount factor, β, equal to 0.98 and a Calvo parameter of 0.63 implying an average price duration of 2.75 quarters. Both parameter estimates are significant at a 99% level and very close to commonly assumed and estimated values.[69] The resulting reduced form slope coefficient, ω', is 0.22 which is very close to the slope of the reduced form estimation.

After generating a benchmark, we will now estimate our CPI Phillips curve (3.33) which additionally depends on changes in the mass of producers. The corresponding orthogonality condition is given by

$$E_t \left\{ \left(\widehat{\pi}_t - \beta\widehat{\pi}_{t+1} - \frac{\zeta - 1}{\theta^c}\widehat{S}_t - \frac{1}{\zeta - 1}\left[\beta\Delta\widehat{N}_{t+1} - \Delta\widehat{N}_t\right] \right) \Lambda_t \right\} = 0 \tag{3.37}$$

In order to show that the impact of the extensive margin has a significant effect on current inflation, we first estimate (3.37) in reduced form. The resulting estimated

[66] Remark: Since we also want to estimate the baseline Phillips curve in structural form we cannot use the standard Phillips curve with Rotemberg adjustment costs as a benchmark because it has two reduced-form parameters but three structural parameters.

[67] Galí and Gertler (1999) take the GDP deflator for generating inflation.

[68] Under rational expectations the forecast error, $\widehat{\pi}_t - \beta\widehat{\pi}_{t+1} - \omega'\widehat{S}_t$, is uncorrelated with past variables – the vector of instruments.

[69] For example Galí (2008) assumes $\beta = 0.99$ and $\vartheta = 2/3$.

equation is given by

$$\widehat{\pi}_t = 0.9895^* E_t \widehat{\pi}_{t+1} + 0.1599^* \widehat{S}_t + 0.3684^* E_t \Delta \widehat{N}_{t+1} - 0.1351^* \Delta \widehat{N}_t \qquad (3.38)$$

Hence, both the future as well as the present change in the mass of producers have a statistically significant impact on CPI inflation which is consistent with our theoretical approach. When comparing the reduced form estimation in (3.38) with that of our benchmark (3.36), it turns out that the slope of the Phillips curve becomes lower in an inflation/labor share-space by introducing the extensive margin. This implies that an endogenous mass of producers causes the impact of the labor share on CPI inflation to decrease since there occur additional effects from changes in the mass of firms.

Finally, we estimate (3.37) in structural form. Also in this case, the GMM estimation delivers very plausible and highly significant parameter values for CPI data. They are shown in Table 3.5 in comparison with the benchmark estimation. Note that the estimation of the CPI Phillips curve (3.37) using PPI data delivers completely insignificant and implausible estimates. This result again indicates the absence of a significant impact of the mass of firms on PPI inflation.

Phillips curve	β	ζ	θ^c	ϑ	ω (ω')
(3.35)	0.9797*			0.6325*	0.2210*
(3.37)	0.9861*	14.6454*	73.1282*		0.1866*

Table 3.5: *Structural parameter estimates [*: 99% significance level]*

The elasticity of substitution between the goods, ζ, is estimated to be 14.65 which is within the commonly applied/estimated range between 3.8 [BGMa, BGMb, Ghironi and Melitz (2005)] and 17 [Uusküla (2008)]. This value thus seems to be plausible. The absolute value of the Rotemberg parameter, θ^c, is hard to interpret as it is commonly set only to obtain an appropriate slope of the Phillips curve. The resulting slope coefficient, ω, in turn becomes slightly lower as in our benchmark estimation which is in line with the reduced form estimations [cf. (3.36) and (3.38)].

The histograms of the estimation errors which respectively result from the structural estimations of (3.35) and (3.37) are depicted in Figure 3.16. The figure indicates that both errors are normally distributed which is supported by the Jarque-Bera test.[70]

The corresponding properties of the estimation errors are finally shown in Table 3.6. It shows that the estimation errors resulting from (3.37) have a mean which is closer to zero, have a lower standard deviation and skewness, and are less autocorrelated in comparison with those resulting from the structural estimation of (3.35). Beside the skewness the differences are however rather small.

[70] The Jarque-Bera test is a goodness-of-fit measure of departure from the normality distribution. It is based on the sample kurtosis and skewness [see Bera and Jarque (1980)].

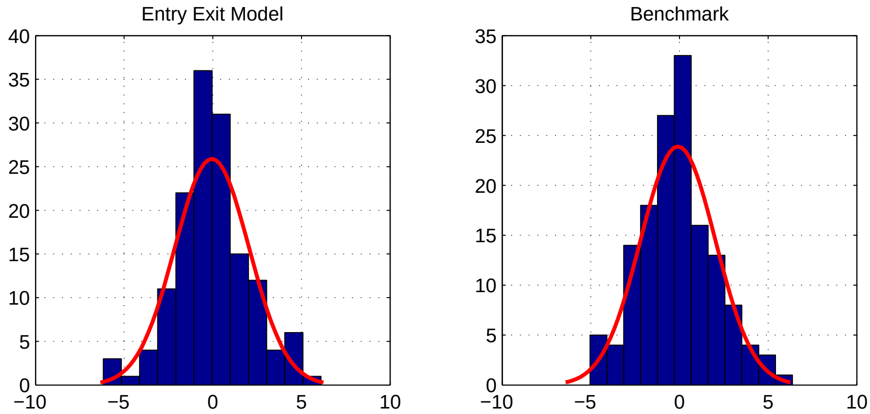

Figure 3.16: *Histograms*

Phillips curve	expected value	standard deviation	skewness	auto-correlation
(3.35)	-0.075	2.107	0.264	-0.240
(3.37)	-0.048	2.096	0.152	-0.216

Table 3.6: *Moments of estimation errors*

All in all, the additional term in the CPI Phillips curve resulting from endogenizing the firm entry and exit is significant. The resulting reduced and structural estimations moreover deliver plausible results which are in line with the underlying theoretical insights.

3.7 Conclusion

As GDP is even more correlated with firm failures than with firm creations and since an endogenous tendency of firms to leave the market is neglected in recent theoretical literature, yet, we build up a totally microfounded New Keynesian model with heterogeneous firms and endogenous firm entry and exit. It turns out that the resulting model – even in a simplified model with exogenous exits – can solve some empirical problems of existing theoretical models which result in counterfactual developments of important economic variables.

In contrast to BGMb, our model generates the empirically observed decrease in inflation in the case of an expansionary technology shock. This result is moreover independent of the assumed degree of shock persistence, i.e. for all $\rho_a \in [0,1)$. Moreover, the RBC specification of our model can depict both a pro-cyclical and a counter-cyclical reaction of total hours worked when varying the Frisch elasticity of labor supply, η^{-1}. Standard RBC models can only depict a positive co-movement which is at odds with the widespread agreement in the empirical literature that there exists a negative correlation between hours worked and GDP. When considering a government spending shock, our model delivers more robust reactions of the mass of firms than the model of BGMa and BGMb where the mass of firms only increases for small ranges of parameter values. Furthermore, BGMb obtain the counter-intuitive result that an expansionary shock to monetary policy, i.e. an exogenous drop in the nominal interest rate, causes the mass of producers to decline. This however conflicts with the empirical findings of Bergin and Corsetti (2008) and Lewis (2009b). In our model a decrease in the interest rate encourages entry. We moreover show that when endogenizing firm exits our model generates an additionally amplification effect which is however very small.

In contrast to BGMa and BGMb, our model performs better than standard RBC and New Keynesian models with respect to the generated second moments since it solves two standard problems of this type of models. First, the standard deviation of hours worked relative to GDP is very close to the empirically observed value and that of consumption is even larger in our model. In the New Keynesian specification, both total hours worked and consumption do not react too smooth relative to output.[71] Second, all variables do not behave too pro-cyclical. These results hold in both the New Keynesian and RBC specification of our model. In comparison with our RBC version, the introduction of sticky prices to the model delivers slightly stronger effects with respect to these two aspects. When assuming exits to be exogenous the results become worse since the autocorrelation of investment becomes rather small and total hours worked reacts too smooth relative to output in this simplified New Keynesian specification.[72] Hence, endogenizing firm exits improves the performance of the model with respect to the second moments. The endogenous counter-cyclical tendency of firms to leave the market should thus not be neglected.

Furthermore, we show that the resulting CPI Phillips curve turns out to be dependent on the extensive margin while PPI inflation – like the baseline NK Phillips curve – is only affected by expected future inflation and the labor share. The GMM estimation of the CPI Phillips curve shows that the impact of the change in the mass of producers on CPI inflation is highly significant and reacts in line with our theoretical findings. Moreover, it turns out that the estimated CPI Phillips curve becomes flatter in an inflation/labor share-space in comparison with the estimated standard NK Phillips curve. This implies that the introduction of an endogenous mass of producers causes the impact of the labor share on inflation to decrease as there occur additional effects from changes in the mass of firms.

By endogenizing firm entry (and exits), our model generates an endogenous trade-off between stabilizing output and inflation for monetary policy. Future research may

[71] This implies that the generated standard deviation of total hours worked and consumption in our framework are not too small in relation to the standard deviation of GDP as in standard RBC and New Keynesian models [cf. King and Rebelo (1999)].

[72] σ_L/σ_Y is then smaller than the empirically observed value.

concern about the optimal monetary policy.

Appendix

Proof of (3.6):

Optimizing (3.5) subjected to the demand for the wholesale good

$$y^w_{j,t} = \left(\frac{P^w_{j,t}}{P_t}\right)^{-\zeta} Y_t \tag{A.3.1}$$

yields

$$\begin{aligned}
\Delta_{0,t}\Bigg[\frac{y^w_{j,t}}{P_t} + \frac{P^w_{j,t}}{P_t}(-\zeta)\frac{(P^w_{j,t})^{-\zeta-1}}{P_t^{-\zeta}}Y_t - mc^w_{j,t}(-\zeta)\frac{(P^w_{j,t})^{-\zeta-1}}{P_t^{-\zeta}}Y_t \\
-\theta^c\left(\frac{P^w_{j,t}}{P^w_{j,t-1}} - \overline{\pi}^w_j\right)\frac{y^w_{j,t}}{P_{j,t-1}} - \frac{\theta^c}{2}\left(\frac{P^w_{j,t}}{P^w_{j,t-1}} - \overline{\pi}^w_j\right)^2(-\zeta)\frac{(P^w_{j,t})^{-\zeta-1}}{P_{j,t}^{-\zeta}}Y_t\Bigg] \\
-\theta^c E_t\left\{\Delta_{0,t+1}\left(\frac{P^w_{j,t+1}}{P^w_{j,t}} - \overline{\pi}^w_j\right)y^w_{j,t+1}\frac{P^w_{j,t+1}}{(P^w_{j,t})^2}\right\} = 0
\end{aligned} \tag{A.3.2}$$

Multiplying by $P_{j,t}/\Delta_{0,t}$ and considering (A.3.1) yields

$$\begin{aligned}
\frac{P^w_{j,t}}{P_t}y^w_{j,t} - \zeta\frac{P^w_{j,t}}{P_t}y^w_{j,t} + \zeta mc^w_t y^w_{j,t} - \theta^c(\pi_{j,t} - \overline{\pi}_j)\pi_{j,t}y^w_{j,t} + \zeta\frac{\theta^c}{2}(\pi_{j,t} - \overline{\pi}_j)^2 y^w_{j,t} \\
+\theta^c E_t\left\{\frac{\Delta_{0,t+1}}{\Delta_{0,t}}(\pi_{j,t+1} - \overline{\pi}_j)\pi_{j,t+1}y^w_{j,t+1}\right\} = 0
\end{aligned} \tag{A.3.3}$$

where $\pi_{j,t} \equiv P^w_{j,t}/P^w_{j,t-1}$. Dividing by $y^w_{j,t}$ yields

$$\begin{aligned}
(\zeta - 1)\rho_{j,t} = \zeta mc^w_{j,t} - \theta^c(\pi_{j,t} - \overline{\pi}_j)\pi_{j,t} + \zeta\frac{\theta^c}{2}(\pi_{j,t} - \overline{\pi}_j)^2 \\
+\theta^c E_t\left\{\frac{\Delta_{0,t+1}}{\Delta_{0,t}}(\pi_{j,t+1} - \overline{\pi}_j)\pi_{j,t+1}\frac{y^w_{j,t+1}}{y^w_{j,t}}\right\}
\end{aligned} \tag{A.3.4}$$

where $\rho_{j,t} \equiv P^w_{j,t}/P_t$. We finally obtain (3.6) by dividing by $(\zeta - 1)$.

Proof of (3.13)

In equilibrium, there exist N_t firms which are Pareto distributed according to $g(z_i)$ where $g(\cdot)$ is the PDF of the Pareto distribution. The price level of a wholesale firm (3.4) then follows:

$$P^w_{j,t} = \left(\int_{z_{\min}}^{\infty} N_t P_{i,t}(z_i)^{1-\zeta} g(z_i) dz_i\right)^{\frac{1}{1-\zeta}} \tag{A.3.5}$$

Inserting the nominal marginal costs (3.8) yields

$$P_{j,t}^{w} = \left(\int_{z_{\min}}^{\infty} N_t \left[\frac{\zeta - 1}{\zeta} \frac{w_t^{nominal}}{A_t z_i} \right]^{1-\zeta} g(z_i) dz_i \right)^{\frac{1}{1-\zeta}}$$

$$= N_t^{\frac{1}{1-\zeta}} \left[\frac{\zeta - 1}{\zeta} \frac{w_t^{nominal}}{A_t} \right] \left(\int_{z_{\min}}^{\infty} z_i^{\zeta-1} g(z_i) dz_i \right)^{\frac{1}{1-\zeta}} \tag{A.3.6}$$

When defining

$$\widetilde{z} \equiv \left[\left(\int_{z_{\min}}^{\infty} z_i^{\zeta-1} g(z_i) dz_i \right)^{\frac{1}{1-\zeta}} \right]^{-1} = \left(\int_{z_{\min}}^{\infty} z_i^{\zeta-1} g(z_i) dz_i \right)^{\frac{1}{\zeta-1}} \tag{A.3.7}$$

it follows that

$$P_{j,t}^{w} = N_t^{\frac{1}{1-\zeta}} \left[\frac{\zeta - 1}{\zeta} \frac{w_t^{nominal}}{A_t} \right] \frac{1}{\widetilde{z}} = N_t^{\frac{1}{1-\zeta}} \underbrace{\left[\frac{\zeta - 1}{\zeta} \frac{w_t^{nominal}}{A_t \widetilde{z}} \right]}_{P_{i,t}(z_i = \widetilde{z})} = N_t^{\frac{1}{1-\zeta}} \widetilde{P}_t \tag{A.3.8}$$

where $\widetilde{P}_t \equiv P_{i,t}(z_i = \widetilde{z})$.

According to symmetry across firms in the wholesale sector, i.e. $P_{j,t}^{w} = P_t^{w} = P_t$, equation (3.13) holds.

Proof of (3.15)

The demand for the intermediate good is given by

$$y_{i,t} = \left(\frac{P_{i,t}}{P_{j,t}^{w}} \right)^{-\zeta} y_{j,t}^{w} \quad \Rightarrow \quad \underbrace{y_{i,t}(z_i = \widetilde{z})}_{\widetilde{y}_t} = \left(\frac{P_{i,t}(z_i = \widetilde{z})}{P_{j,t}^{w}} \right)^{-\zeta} y_{j,t}^{w} \tag{A.3.9}$$

Inserting (A.3.8) yields

$$\widetilde{y}_t = \left(\frac{\widetilde{P}_t}{N_t^{\frac{1}{1-\zeta}} \widetilde{P}_t} \right)^{-\zeta} y_{j,t}^{w} = N_t^{-\frac{\zeta}{\zeta-1}} y_{j,t}^{w} \quad \Leftrightarrow \quad y_{j,t}^{w} = N_t^{\frac{\zeta}{\zeta-1}} \widetilde{y}_t \tag{A.3.10}$$

According to symmetry across firms in the wholesale sector, i.e. $y_{j,t}^{w} = y_t^{w} = Y_t$, equation (3.15) holds.

Proof of (3.29)

A firm i sets its real price, $\rho_{i,t}$, as a constant mark-up $\zeta/(\zeta - 1)$ over its marginal costs, $mc_{i,t}$ such that

$$\rho_{i,t} - mc_{i,t} = \left[\frac{\zeta}{\zeta - 1} - 1 \right] mc_{i,t} = \frac{1}{\zeta} mc_{i,t} \tag{A.3.11}$$

For the threshold $z_i = \delta_t^{in}$ inequality (3.9) holds with equality

$$[\rho_{i,t}(z_i = \delta_t^{in}) - mc_{i,t}(z_i = \delta_t^{in})]y_{i,t}(z_i = \delta_t^{in}) + E_t\left\{\Delta_{t,t+1}\Psi_{t+1}\right\} = f_E mc_{i,t}(z_i = \delta_t^{in}) \tag{A.3.12}$$

where $mc_{i,t}(z_i = \delta_t^{in}) = w_t/(A_t\delta_t^{in})$ and $y_{i,t}(z_i = \delta_t^{in}) = A_t\delta_t^{in}l_t$ and $E_t\Delta_{t,t+1} = E_t\Delta_{0,t+1}/\Delta_{0,t}$. Inserting these expressions and (A.3.11) in (A.3.12) yields

$$\frac{1}{\zeta}\frac{w_t}{A_t\delta_t}A_t\delta_t l_t + E_t\left\{\Delta_{t,t+1}\Psi_{t+1}\right\} = f_E\frac{w_t}{A_t\delta_t} \tag{A.3.13}$$

Note that

$$\frac{w_t}{A_t\delta_t^{in}} = \frac{w_t}{A_t\widetilde{z}}\frac{\widetilde{z}}{\delta_t^{in}} = \widetilde{mc}_t\frac{\widetilde{z}}{\delta_t^{in}} \tag{A.3.14}$$

where $\widetilde{mc}_t = w_t/(A_t\widetilde{z})$.

Inserting (A.3.14) in (A.3.13) yields

$$\frac{1}{\zeta}w_t l_t + E_t\left\{\Delta_{t,t+1}\Psi_{t+1}\right\} = f_E\widetilde{mc}_t\frac{\widetilde{z}}{\delta_t^{in}} \tag{A.3.15}$$

The total differential of (A.3.15) is given by

$$\begin{aligned}
&\frac{1}{\zeta}l\mathrm{d}w_t + \frac{1}{\zeta}w\mathrm{d}l_t + \Psi\mathrm{d}E_t\Delta_{t,t+1} + \Delta\mathrm{d}E_t\Psi_{t+1} = f_E\frac{\widetilde{z}}{\delta^{in}}\mathrm{d}\widetilde{mc}_t - f_E\widetilde{mc}\frac{\widetilde{z}}{(\delta^{in})^2}\mathrm{d}\delta_t^{in}\\
&\frac{1}{\zeta}wl\left(\frac{\mathrm{d}w_t}{w} + \frac{\mathrm{d}l_t}{l}\right) + \Psi\Delta\left(\frac{\mathrm{d}E_t\Psi_t}{\Psi} + \frac{\mathrm{d}E_t\Delta_{t,t+1}}{\Delta}\right) = f_E\widetilde{mc}\frac{\widetilde{z}}{\delta^{in}}\left(\frac{\mathrm{d}\widetilde{mc}_t}{\widetilde{mc}} - \frac{\mathrm{d}\delta_t^{in}}{\delta^{in}}\right)
\end{aligned} \tag{A.3.16}$$

When denoting a log-linearized variable with $\widehat{X}_t = \mathrm{d}X_t/X$, we obtain

$$\begin{aligned}
&\frac{1}{\zeta}wl(\widehat{w}_t + \widehat{l}_t) + \Psi\Delta(E_t\widehat{\Psi}_t + E_t\widehat{\Delta}_{t,t+1}) = f_E\widetilde{mc}\frac{\widetilde{z}}{\delta^{in}}(\widehat{mc}_t - \widehat{\delta}_t^{in})\\
\Leftrightarrow\quad &\widehat{mc}_t = \widehat{\delta}_t^{in} + \frac{\Psi}{f_E\widetilde{mc}\frac{\widetilde{z}}{\delta^{in}}}\left[\widehat{w}_t + \widehat{l}_t + \Delta E_t\widehat{\Psi}_t + E_t\widehat{\Delta}_{t,t+1}\right]
\end{aligned} \tag{A.3.17}$$

where the steady state of per period profits is given by $\Psi = (\rho - mc)y = \frac{1}{\zeta}wl$. As in Chapter 2, the stochastic real discount factor is given by $E_t\Delta_{t,t+1} = \beta\left(\frac{E_tC_{t+1}}{C_t}\right)^{-\sigma}$ implying $\Delta = \beta$ and $E_t\widehat{\Delta}_{t,t+1} = \beta\sigma(\widehat{C}_t - E_t\widehat{C}_{t+1})$. Moreover, we calibrate $\widetilde{z} = 1$ to deliver comparable results with models without heterogenous firms. Inserting the latter expressions in (A.3.17) yields equation (3.29).

The steady state of δ_t^{in} is obtained by calibrating the steady state entry rate to the empirically observed value and by equation (3.12) in steady state.

Proof of (3.32):

The marginal costs, $\widetilde{mc}_t$, are given by

$$\widetilde{mc}_t = \frac{w_t}{A_t \widetilde{z}} \tag{A.3.18}$$

or in log-linear form

$$\widehat{mc}_t = \widehat{w}_t - \widehat{A}_t \tag{A.3.19}$$

The aggregated production function is given by (3.16) or in log-linear form

$$\widehat{Y}_t = \widehat{A}_t + \frac{1}{\zeta - 1}\widehat{N}_t + \widehat{L}_t \quad \Leftrightarrow \quad \widehat{A}_t = \widehat{Y}_t - \frac{1}{\zeta - 1}\widehat{N}_t - \widehat{L}_t \tag{A.3.20}$$

Inserting (A.3.20) in (A.3.19) yields

$$\widehat{mc}_t = \widehat{w}_t - \widehat{Y}_t + \widehat{L}_t + \frac{1}{\zeta - 1}\widehat{N}_t \tag{A.3.21}$$

When finally inserting (A.3.21) in (3.28), we obtain equation (3.32):

$$\begin{aligned}
\widehat{\widehat{\pi}}_t &= \beta E_t \widehat{\widehat{\pi}}_t + \frac{\zeta - 1}{\theta^c}\widehat{mc}_t - \frac{1}{\theta^c}\widehat{N}_t \\
&= \beta E_t \widehat{\widehat{\pi}}_t + \frac{\zeta - 1}{\theta^c}\left[\widehat{w}_t - \widehat{Y}_t + \widehat{L}_t + \frac{1}{\zeta - 1}\widehat{N}_t\right] - \frac{1}{\theta^c}\widehat{N}_t \\
&= \beta E_t \widehat{\widehat{\pi}}_t + \frac{\zeta - 1}{\theta^c}\underbrace{\left[\widehat{w}_t + \widehat{L}_t - \widehat{Y}_t\right]}_{\widehat{S}_t} \qquad \text{(A.3.22)}
\end{aligned}$$

Models

The complete New Keynesian model with endogenous firm entry and exit in log-linear form is given by

$$\begin{aligned} Y_t = {} & \frac{C}{Y}C_t + \frac{G}{Y}G_t + \frac{mc\phi N f_E}{Y}[\phi_{t-1} + mc_t + N_t] \\ & + \frac{mc\gamma N f_E}{Y}(\gamma_t + mc_t + N_t) \end{aligned} \tag{A.3.23}$$

$$C_t = C_{t+1} - \frac{1}{\sigma}[r_t - \pi_{t+1}^{CPI}] \tag{A.3.24}$$

$$w_t = \eta L_t + \sigma C_t \tag{A.3.25}$$

$$Y_t = A_t + \rho_t + L_t \tag{A.3.26}$$

$$w_t = A_t + mc_t \tag{A.3.27}$$

$$\phi_t = -k\delta_t^{in} \tag{A.3.28}$$

$$\gamma_t = \frac{(k\delta^{out})^{-k}}{z_m in^{-k} - (\delta^{out})^{-k}}\delta_t^{out} \tag{A.3.29}$$

$$N_t = (1-\phi-\gamma)N_{t-1} + \phi\frac{N^{max} - N}{N}\phi_{t-1} - \gamma\gamma_t \tag{A.3.30}$$

$$\frac{f_X mc}{\Psi}(w_t - A_t - \delta^{out}\delta_t^{out}) = w_t + l_t + \beta\Psi_{t+1} + \beta\sigma(C_t - C_{t+1}) \tag{A.3.31}$$

$$\frac{f_E mc}{\Psi}(w_t - A_t - \delta^{in}\delta_t^{in}) = w_t + l_t + \beta\Psi_{t+1} + \beta\sigma(C_t - C_{t+1}) \tag{A.3.32}$$

$$\begin{aligned} \Psi_{t+1} = {} & \frac{1}{1-\beta(1-\gamma)}[A_{t+1} + l_{t+1} + \frac{\rho}{\rho - mc}\rho_{t+1} - \frac{mc}{\rho - mc}mc_{t+1} - \frac{\gamma}{1-\gamma}\gamma_{t+1}] \\ & + \beta(1-\gamma)\Psi_{t+2} - \beta\gamma\gamma_{t+2} + \beta(1-\gamma)\sigma(C_{t+1} - C_{t+2}) \end{aligned} \tag{A.3.33}$$

$$\rho_t = mc_t - \frac{\theta^c}{\zeta - 1}(\pi_t^{PPI} - \beta\pi_{t+1}^{PPI}) \tag{A.3.34}$$

$$r_t = \varrho r_{t-1} + (1-\varrho)(\lambda_\pi \pi_t + \lambda_y Y_t) + \kappa_t \tag{A.3.35}$$

$$\pi_t^{PPI} = \pi_t + \frac{1}{1-\zeta}(N_{t-1} - N_t) \tag{A.3.36}$$

$$\rho_t = \frac{1}{\zeta - 1}N_t \tag{A.3.37}$$

$$y = \frac{\zeta}{1-\zeta}N_t + Y_t \tag{A.3.38}$$

$$l_t = L_t - N_t \tag{A.3.39}$$

Steady State Values

C	0.71	Ψ	0.77	Y	0.90	δ^{in}	1.59	δ^{out}	0.54
γ	0.025	ϕ	0.025	mc	0.94	π	1.00	$\widetilde{\pi}$	1.00
G	0.16	N	0.5	ρ	1.29	R	1.01		

Table 3.7: *Numerically computed steady state values*

The RBC model with endogenous firm entries and exits

The RBC model with endogenous firm entry and exit considering capital is given by

$$Y_t = N_t^{\frac{\zeta}{\zeta-1}} \widetilde{y}_t \tag{A.3.40}$$

$$Y_t = A_t \widetilde{z} N_t^{\frac{1}{\zeta-1}} L_t^{1-\alpha} K_t^{\alpha} \tag{A.3.41}$$

$$I_t = E_t K_{t+1} - (1-\delta^k) K_t \tag{A.3.42}$$

$$w_t = \chi L_t^{\eta} C_t^{\sigma} \tag{A.3.43}$$

$$C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} R_{t+1} \right\} \tag{A.3.44}$$

$$C_t^{-\sigma} = \beta E_t \left\{ C_{t+1}^{-\sigma} [r_{t+1}^k - (1-\delta^k)] \right\} \tag{A.3.45}$$

$$C_t = Y_t - G_t - I_t - N_t \widetilde{mc}_t (f_E \phi_{t-1} + f_X \gamma_t) \tag{A.3.46}$$

$$\widetilde{mc}_t = \frac{w_t}{A_t \widetilde{z} (1-\alpha) \left(\frac{K_t}{L_t} \right)^{\alpha}} \tag{A.3.47}$$

$$r_t^K = \frac{\alpha}{1-\alpha} \frac{L_t}{K_t} \tag{A.3.48}$$

$$N_t = \phi_{t-1} N^{\max} + N_{t-1}(1 - \phi_{t-1} - \gamma_t) \tag{A.3.49}$$

$$\phi_t = 1 - \Gamma(\delta_t^{in}), \quad \gamma_t = \Gamma(\delta_t^{out}) \tag{A.3.50}$$

$$\widetilde{\rho}_t = N_t^{\frac{1}{\zeta-1}} \tag{A.3.51}$$

$$f_E mc_t(\delta_t^{in}) = \frac{1}{\zeta - 1} mc_t(\delta_t^{in}) y_t(\delta_t^{in}) + \frac{E_t \Delta_{0,t+1}}{\Delta_{0,t}} E_t \Psi_{t+1}(\delta_t^{in}) \tag{A.3.52}$$

$$f_E mc_t(\delta_t^{out}) = \frac{1}{\zeta - 1} mc_t(\delta_t^{out}) y_t(\delta_t^{out}) + \frac{E_t \Delta_{0,t+1}}{\Delta_{0,t}} E_t \Psi_{t+1}(\delta_t^{out}) \tag{A.3.53}$$

Part Two: Monetary and Fiscal Policy Analyses

4 Barro-Gordon Revisited: An Analysis of Reputational Equilibria in a New Keynesian Model

4.1 Introduction

In order to fight the recessionary impacts of the financial crisis 2007-2009 central banks around the globe switched over to discretionary monetary policy. As the financial crisis seems to be overcome, monetary authorities have however to think about exit strategies and thus a way to credibly return to a commitment monetary policy. The topic of policy switching regimes and the resulting consequences for the credibility of central banks are already discussed in the famous study of Barro and Gordon (1983a,b). However, their framework is completely represented by a traditional Phillips curve, i.e. the authors do not consider any demand side effects which also played a crucial role in the subprime crisis. The authors moreover assume that the Central Bank can directly control for the inflation rate. More precisely, Barro and Gordon (1983a,b) assume that the policymaker controls an instrument which has a direct connection to the inflation rate – for instance, the money growth rate.[1]

The aim of this chapter[2] is not to depict the decision problem of a monetary authority under the circumstances of the financial crisis. Instead, this chapter offers an approach which enables us to discuss both the debate in the New Keynesian literature about the optimality of commitment vs. discretion and the time-inconsistency problem à la Kydland and Prescott (1977) and Barro and Gordon (1983a,b) combined in a unified framework.[3] Within the standard New Keynesian model we can solve the inconsistency problem and derive time-consistent (or: stable) interest rate rules of Taylor-type. Thereby, this framework enables us to consider the demand side of the economy and to deviate from the assumption that the central bank can directly control for the inflation rate. Instead, the mechanism in New Keynesian models is as follows. (i) The central bank commits itself to follow an interest rate

[1] Jarchow (2010, Chapter 5) also extends the Kydland/Prescott-Barro/Gordon approach for a demand side. However, this equation just determines the money growth rate. Jarchow (2010, Chapter 5) moreover analyzes optimal monetary commitment and discretion strategies within this framework.

[2] For a different version of this Chapter see ”Barro-Gordon revisited: Reputational equilibria in a New Keynesian Model” (with H.-W. Wohltmann), March 2010, Economics Working Paper 2010-04, Department of Economics, Christian-Albrechts-Universität zu Kiel.

[3] See Wohltmann and Krömer (1989) for a comment on the different concepts of time-consistency in the economics literature.

rule of Taylor-type. (ii) Private agents form inflation expectations. (iii) The central bank sets the interest rate and the households adjust their consumption expenditures according to the Euler consumption equation. (iv) Inflation is then determined by expected future inflation and the output realization via the New Keynesian Phillips curve.

There already exists a couple of studies which show that the crucial assumption made by Barro and Gordon (1983a,b) introducing the time-inconsistency problem – namely, that the central bank aims at an output gap target larger than zero – leads to an inflation bias in a New Keynesian framework [see amongst others Clarida, Galí, and Gertler (1999)]. However, an explicit derivation and the analysis of the resulting welfare consequences of the optimal monetary policy, including purely discretionary and inconsistent monetary policy as well as time-(in)consistent Taylor rules, are neglected in the literature.

Our main findings are as follows. Under a completely standard calibration including a time preference rate of the monetary authority equal to the long-run interest rate, the standard Taylor rule is time-consistent (or: stable) in the presence of a cost-push shock. The central bank thus does not have an incentive to deviate from the announced rule and to switch over to the inconsistent policy regime. However, there exists a multiplicity of stable Taylor rules which are superior to the standard one. In contrast to the Kydland/Prescott-Barro/Gordon approach, implementing a monetary rule such that the cost and benefit resulting from inconsistent policy coincide – which implies a net gain of inconsistent policy behavior equal to zero – is *not* optimal. Instead, the solution can be enhanced by moving into the time-consistent area where the net gain of inconsistent monetary policy is negative. Moreover, there does not exist a stable monetary policy rule maximizing the welfare when considering monetary policy of Taylor-type rules. The continuum of stable rules furthermore becomes larger when assuming an additional term in the social loss function concerning interest rate stability. This implies that the reputation of the central bank naturally improves if the policy maker is also concerned about stabilizing the interest rate. Our results remain robust with respect to the analysis of simultaneous supply and demand shocks.

The remainder is organized as follows. Section 2 shortly describes the applied model. In Section 3, we turn to monetary policy issues including the optimal discretionary monetary policy, simple Taylor rules, and the incentive to deviate from the announced policy rule. We moreover derive the continuum of time-consistent Taylor rules, discuss the problem of finding an optimal stable rule, and check our results for robustness. The last section concludes.

4.2 The Model

For the sake of simplicity, we apply a static approximation of the microfounded canonical New Keynesian model following Bofinger, Meyer, and Wollmershäuser (2006).[4] The model can be represented by a three-dimensional equation system including an IS curve, a Phillips curve, and a monetary policy rule. The IS curve is given by

$$x = a - br + \varepsilon_1 \tag{4.1}$$

where x denotes the output gap which is defined as the deviation of output from its natural level. a is a constant. b represents the intertemporal elasticity of substitution. r is the real interest rate. As shown in the Appendix, the demand shock, ε_1, can also be interpreted as a shock to aggregate technology or innovation.[5]

The second building block of the model is the static approximation of the New Keynesian Phillips curve

$$\pi = \pi^e + \delta x + \varepsilon_2 \tag{4.2}$$

where π and π^e represent current and expected future inflation, respectively. δ is the slope of the Phillips curve. ε_2 represents a cost-push shock.

In contrast to the demand shock, the supply shock causes a trade-off for the monetary authority between stabilizing output and inflation. Therefore, we will restrict our analysis to cost-push shocks. However, we will re-consider the demand shock for a robustness check at the end of our analysis.

4.3 Monetary Policy

In the following, we will discuss different types of policy regimes, namely the optimal discretionary monetary policy, D, the commitment regime à la Taylor, TR, and the regime under inconsistent policy, IP. Independently of the assumed type of monetary policy, the central bank seeks to minimize a social loss function.

As shown by Galí (2008, Chapter 4) and Woodford (2003, Chapter 6), the second order approximation of the households' utility function delivers a quadratic loss function which represents flexible inflation targeting in the spirit of Svensson (1999).

[4] Bofinger, Meyer, and Wollmershäuser (2006) already highlight that their approach can be extended for implementing the Kydland/Prescott-Barro/Gordon approach. However, they only point out that an output gap target above zero as assumed in Barro and Gordon (1983a) leads to an inflation bias which was already shown by Clarida, Galí, and Gertler (1999) within the dynamic New Keynesian model.

[5] In the dynamic version of the standard New Keynesian model, it can moreover be shown that in the case of an expansionary but persistent technology shock, the resulting demand shock is contractionary because the current output level reacts less expansionary than its natural counterpart. The output gap consequently declines. In the case of a permanent innovation, the resulting technology shock however has an expansionary impact on the output gap.

The static approximation of this function is given by

$$V = (\pi - \pi^T)^2 + \lambda x^2 \tag{4.3}$$

where π^T represents the target inflation rate and $\lambda \in [0,1]$ is the central bank's preference parameter on stabilizing the output gap. In the case $\lambda = 0$, the central bank's preferences represent a strict inflation targeting regime, i.e. the monetary authority is just concerned about stabilizing inflation.

Following Barro and Gordon (1983a,b), we additionally assume that the monetary authority's target of the output gap is positive, i.e. $x^T > 0$. An economic rationale is that e.g. monopolistic distortions or taxes keep potential output below its efficient level [see Clarida, Galí, and Gertler (1999)]. Then the social loss is given by

$$V = (\pi - \pi^T)^2 + \lambda(x - x^T)^2 \tag{4.4}$$

An alternative approach to include the problem of time-inconsistency into the model is to assume an asymmetric loss function [see Cukiermann and Gerlach (2003), Nobay and Peel (2003), or Ruge-Murcia (2003)]. There is empirical evidence for both approaches [see for instance Ireland (1999) and Gerlach (2003)]. However, there is no micro-foundation for such a loss function, at all. We moreover want to remain as close as possible to the Kydland/Prescott-Barro/Gordon approach.

4.3.1 Discretionary Monetary Policy

In this section, we will derive the optimal discretionary monetary policy. In this regime, the expected inflation rate is taken as given for the central bank since the monetary authority applies a sequential optimization. Therefore, it is unable to make credible announcements concerning the design of monetary policy that could influence private expectations.

The central bank minimizes the social loss (4.4) subjected to the Phillips curve (4.2).[6] Inserting the Phillips curve (4.2) in the social loss function (4.4) and optimizing the resulting equation with respect to the output gap yields the following first order condition:

$$2\delta(\pi^e + \delta x + \varepsilon_2 - \pi^T) + 2\lambda(x - x^T) = 0 \tag{4.5}$$

Following Barro and Gordon (1983a,b), we assume that private expectations about inflation are formed before the shocks occur. This implies that when forming expectations about inflation, the shocks (ε_1 and ε_2) are not included in the information set of private agents [see also Walsh (2010, Chapter 8), Lohmann (1992), or Persson and Tabellini (1990)].

[6] Note that the IS curve is not a binding restriction in this case. However, the demand side is essential for the simple rule analysis and when considering simultaneous supply and demand shocks.

Inserting (4.5) in the Phillips curve and taking rational expectations conditional on the set of private information, I, with $E[\varepsilon_2|I] = 0$, yields the expected inflation rate under discretionary monetary policy.

$$\pi^e|_D = \pi^T + \frac{\lambda}{\delta}x^T \tag{4.6}$$

Note that in the case of a flexible inflation targeting regime implying $\lambda > 0$, expected inflation is above the central bank's target level when the monetary authority aims at a positive output gap.

Combining (4.5) and (4.6) yields the solution path of the output gap.

$$x|_D = -\frac{\delta}{\delta^2 + \lambda}\varepsilon_2 \tag{4.7}$$

The solution of the output gap is independent of the corresponding target level, x^T, and moreover coincides with the discretionary solution in the case where the central bank does not target a positive output gap, i.e. $x|_D^{x^T>0} = x|_D^{x^T=0}$.

However, this does not hold for the solution of inflation. By inserting (4.6) and (4.7) in the Phillips curve, we obtain

$$\pi|_D = \pi^T + \frac{\lambda}{\delta}x^T + \frac{\lambda}{\lambda + \delta^2}\varepsilon_2 \tag{4.8}$$

The central bank's target level of the output gap represents an inflation bias in the solution of inflation which pushes inflation above its target level. Since under rational expectations the model structure including the loss function is known by private agents, the intention of the central bank to push the output gap above its natural level fails. Instead, the solution of output remains unchanged and that of inflation is 'biased'. This result also holds in the absence of a supply shock, i.e. $\varepsilon_2 = 0$.[7]

Moreover, equation (4.8) implies that inflation only coincides with its target level when the central bank's preferences represent strict inflation targeting ($\lambda = 0$). This is a very intuitive result since in this case the central bank is not concerned about the output gap, at all.

When combining (4.7) and (4.8), discretionary monetary policy can be expressed as a targeting rule [see Svensson (1999)] given by

$$x|_D - x^T = -\frac{\delta}{\lambda}\left[\pi|_D - \pi^T\right] \tag{4.9}$$

implying a negative relationship between the stabilization of inflation and the output gap at the respective target level.

[7] Remark: In the absence of the supply shock all results remain qualitatively unchanged. In fact, the assumption of the supply shock biases our results towards optimal discretion. However, we want to simultaneously discuss the inflation bias and the optimal discretion vs. commitment debate within a unitary framework in this chapter.

Finally, the social loss under discretionary monetary policy can be derived by inserting the solutions of the output gap (4.7) and inflation (4.8) in the welfare function (4.4).

$$V|_D = \frac{\lambda}{\lambda + \delta^2}\left[\frac{\delta^2 + \lambda}{\delta}x^T + \varepsilon_2\right]^2 \tag{4.10}$$

If the cost-push shock is existent, i.e. $\varepsilon_2 \neq 0$, the loss is strictly positive as long as $\lambda > 0$.

4.3.2 Simple Rules

In this section, we will derive the social loss when the central bank credibly commits itself to follow a simple monetary policy rule of Taylor-type. Since the commitment is credible in this case, the central bank influences private expectations in this policy regime.

The Taylor rule is commonly represented as

$$i = i^T + k_\pi(\pi - \pi^T) + k_x(x - x^T) \tag{4.11}$$

where k_x and k_π are the elasticities of the nominal interest rate, i, with respect to the deviation of the output gap and the inflation rate from their respective target level. In the following, we will refer to them as Taylor rule coefficients. The real interest rate which is the argument of the IS curve (4.1) is then obtained from the nominal interest rate via the well-known Fisher equation.

As shown by Bullard and Mitra (2002), the following condition is necessary to ensure that the dynamic counterpart of our model has a unique and stable equilibrium [see also Walsh (2010, Chapter 5)]

$$\delta(k_\pi - 1) + (1 - \beta)k_x > 0 \tag{4.12}$$

where $\beta \in [0, 1]$ is the discount factor of private households. The stability of the whole system thus crucially depends on the Taylor rule coefficients. In the following, we will assume that the Taylor principle, $k_\pi > 1$, and the condition $k_x \geq 0$ hold. Then the stability condition (4.12) is obviously satisfied.

i^T is the central bank's target level of the nominal interest rate which follows

$$i^T = r^T + \pi^T \tag{4.13}$$

The corresponding target level of the real interest rate, r^T, follows from the IS equation and is given by

$$r^T = \frac{1}{b}(a - x^T) \tag{4.14}$$

Note that the target level of the real interest rate coincides with its natural level, $r^n = \frac{a}{b}$, in the borderline case $x^T = 0$.

Combining the Taylor rule (4.11) with (4.13), (4.14), the IS curve (4.1), and the Phillips curve (4.2) and taking rational expectations, yields expected inflation rate under the monetary policy regime TR.

$$\pi^e|_{TR} = \pi^T + \frac{1 + bk_x}{b(k_\pi - 1)} x^T \tag{4.15}$$

As long as $k_\pi > 1$ and $k_x \geq 0$, expected inflation exceeds the target level when the monetary authority seeks to achieve a positive target level of the output gap. Since we consider an ad hoc Taylor rule for the moment, the expected inflation rate is however independent of the central bank's preferences on stabilizing output. By contrast and as shown in the last section, under optimal discretionary monetary policy expected inflation exceeds its target level only in the case of flexible inflation targeting, $\lambda > 0$ (cf. equation (4.6)).

When combining (4.15) and the Phillips curve (4.2), we obtain the solution path of the output gap and the inflation rate

$$x|_{TR} = -\frac{bk_\pi}{\alpha} \varepsilon_2 \tag{4.16}$$

$$\pi|_{TR} = \pi^T + \frac{1 + bk_x}{b(k_\pi - 1)} x^T + \frac{1 + bk_x}{\alpha} \varepsilon_2 \tag{4.17}$$

where $\alpha \equiv 1 + b(k_x + \delta k_\pi)$. Equivalently to the case of the discretionary monetary policy, the solution of the output gap is independent of its target level. Hence, equation (4.16) also represents the solution of the borderline case $x^T = 0$ where the central bank targets a closed output gap. Again, this result does not hold for the solution of inflation since inflation is biased. Considering a positive target level of the output gap thus leads to higher inflation while the resulting output gap remains unchanged.[8]

In order to obtain the social loss under the policy regime TR for arbitrary coefficients k_π and k_x, we finally insert the solutions of the output gap and inflation in the welfare function (4.4).

$$V|_{TR} = (1 + bk_x)^2 \left[\frac{1}{b(k_\pi - 1)} x^T + \frac{1}{\alpha} \varepsilon_2 \right]^2 + \lambda \left[x^T + \frac{bk_\pi}{\alpha} \varepsilon_2 \right]^2 \tag{4.18}$$

From (4.18) it directly follows that the social loss approaches infinity, if k_π tends to unity. In this limit case the social loss *exceeds* that under discretionary monetary policy (4.10). The rationale is the reaction of expected inflation which according to (4.15) also tends to infinity, if $k_\pi \to 1$. The following numerical example however

[8] Note that this result also holds when assuming $\varepsilon_2 = 0$.

shows that when applying a standard calibration, the social loss under discretionary monetary policy clearly exceeds that under TR. The Taylor rule regime is then preferable.

As standard in the New Keynesian literature, we assume the intertemporal elasticity of substitution, b, to be equal to one. Under commonly chosen deep parameters, the slope of the Phillips curve is 0.0858 implying an average price duration of four quarters and an annual nominal interest rate of about 4%. Following Svensson (1999), we set the flexible inflation targeting parameter λ to 0.5. We arbitrarily assume the target level of the output gap to be 0.1 implying that the potential output level is 10% higher than the current one. The shock impact is normalized to one.

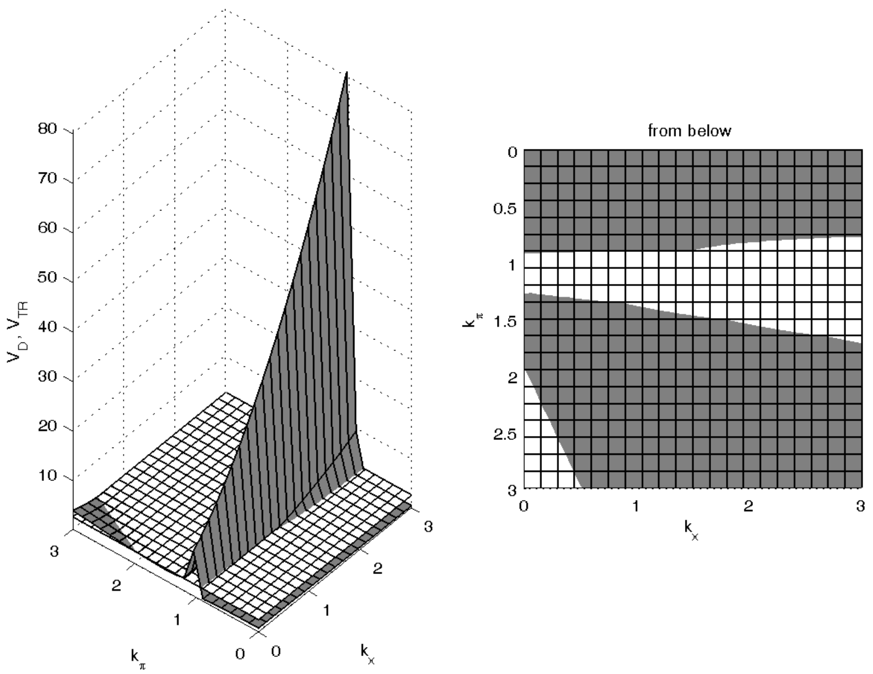

Figure 4.1: *Comparing the social loss under the regime TR [grey area] and D [white area]*

Under this standard calibration, Figure 4.1 depicts the social loss in the regime TR for different combinations of k_π and k_x [grey area] as well as the loss under regime D [white shaded area]. The social loss under TR can exceed that under D, when the Taylor rule coefficient k_π tends to unity. However, if k_π is sufficiently larger than one and k_x is sufficiently larger than zero, $V|_{TR}$ is preferable to $V|_D$.[9]

In the case of standard Taylor rule, i.e. $k_\pi = 1.5$ and $k_x = 0.5$, the social loss in

[9]Note that there also exists a small area with $V|_{TR} > V|_D$, if k_x is sufficiently small and k_π is sufficiently large.

the regime TR is significantly lower than in the discretionary case. The numerical evaluation of $V|_D$ and $V|_{TR}$ yields

$$V|_{TR} = 2.0120 < 2.4956 = V|_D \tag{4.19}$$

The credible commitment to the standard monetary policy rule yields a significant welfare gain via the expectation channel which is not active in the discretionary case.[10] The social loss under D exceeds that under TR by about 24%.

4.3.3 Inconsistent Policy

In this section, we will show that the central bank has an incentive to deviate from the announced Taylor rule and thus renege on their commitment if the monetary authority is faced with a purely static one-period optimization approach.

If the central bank credibly announces to follow a specifically calibrated Taylor rule, expected inflation is tied at a given level according to (4.15). However, the central bank can then achieve a welfare gain by re-optimizing in a discretionary manner. In this case, the monetary authority will not implement the announced policy rule. We will refer to this policy regime as inconsistent monetary policy, IP.

The maximization problem of the central bank under IP is given by

$$\begin{aligned} \max_{x,\,\pi} \quad & L = (\pi - \pi^T)^2 + \lambda(x - x^T)^2 \\ \text{s.t.} \quad & \pi = \pi^e + \delta x + \varepsilon_2 \\ & \pi^e = \pi^e|_{TR} \end{aligned} \tag{4.20}$$

As in the discretionary case, the first order condition with respect to the output gap is given by

$$x|_{IP} = -\frac{\delta}{\lambda + \delta^2}\left[\pi^e|_{TR} - \pi^T + \varepsilon_2\right] + \frac{\lambda}{\lambda + \delta^2} x^T \tag{4.21}$$

Equation (4.21) just deviates from (4.5) via the formation of the expected inflation rate.

By inserting (4.15) in (4.21), we obtain the solution of the output gap under the inconsistent policy regime, IP.

$$x|_{IP} = \frac{1}{\lambda + \delta^2}\left[\lambda - \frac{\delta(1 + bk_x)}{b(k_\pi - 1)}\right] x^T - \frac{\delta}{\lambda + \delta^2}\varepsilon_2 \tag{4.22}$$

In contrast to the purely discretionary monetary policy and the regime under commitment to a Taylor rule, the solution of the output gap (4.22) now depends on its

[10] Remark: In the dynamic New Keynesian framework, Clarida, Galí, and Gertler (1999) and Woodford (1999) show that a commitment strategy can be advantageous even in the absence of the inflation bias. See also Dennis (2010) for an insightful discussion of this topic.

target level.[11] This implies that the central bank's intention to push output above its natural level can now be achieved.

The solution of inflation is obtained from (4.22) via the Phillips curve (4.2).

$$\pi|_{IP} = \pi^T + \frac{\lambda}{\lambda + \delta^2}\left[\frac{\alpha - \delta b}{b(k_\pi - 1)} x^T + \varepsilon_2\right] \tag{4.23}$$

In line with our previous finding under discretionary monetary policy, inflation only coincides with its target level when the central bank follows strict inflation targeting.

The combination of (4.22) and (4.23) necessarily yields the same targeting rule as in the discretionary case (cf. equation (4.9)):

$$x|_{IP} - x^T = -\frac{\delta}{\lambda}\left[\pi|_{IP} - \pi^T\right] \tag{4.24}$$

The social loss under inconsistent monetary policy can finally be obtained by inserting (4.22) and (4.23) in (4.4).

$$V|_{IP} = \frac{\lambda}{\lambda + \delta^2}\left[\frac{\alpha - \delta b}{b(k_\pi - 1)} x^T + \varepsilon_2\right]^2 \tag{4.25}$$

By definition, $V|_{TR}$ must exceed $V|_{IP}$, i.e. the deviation from the announced Taylor rule yields a welfare enhancement. The numerical evaluation for the two policy regimes under the standard parameterizations delivers

$$V|_{IP} = 1.6875 < 2.0120 = V|_{TR} \tag{4.26}$$

The welfare gain resulting from the inconsistent policy regime if the monetary authority credibly announces to follow a standard Taylor rule is thus about 19%.

4.3.4 Time-Consistent Simple Rules

In this section, we will derive a continuum of time-consistent (or: stable) simple rules. This is done by assuming a long-run planning horizon of the monetary authority as in Barro and Gordon (1983a,b).

As shown in the previous section, the central bank has an incentive to re-optimize, if it can credibly announce to follow a commitment strategy. If its announcements are not credible, private expectations are given for the central bank and the monetary authority should follow a discretionary monetary policy. By assuming that the central bank looses its reputation, if it deviates once from its announcement, i.e. if the central bank switches over to the regime IP, one can find both a continuum of time-consistent and time-inconsistent simple rules. More precisely, we assume a punishment interval of one period implying that the central bank looses its reputation

[11] Again, it is worth mentioning that this result also holds if $\varepsilon_2 = 0$.

for exactly one period when reneging on their commitment once.[12] The announcements of the central bank will then no longer be credible such that private agents will form their expectations as in the discretionary case.

In this framework à la Barro and Gordon (1983a,b), the central bank is faced with a simple cost-benefit calculation where the benefit, B, is the welfare gain resulting from the inconsistent policy in comparison to the implementation of the announced Taylor rule, $V|_{TR} - V|_{IP}$. The cost, C, is the discounted next period welfare loss resulting from the sacrifice in the central bank's reputation, $V|_D - V|_{TR}$. The net gain, N, of the inconsistent policy is then given by[13]

$$N = B - C = (V|_{TR} - V|_{IP}) - \frac{1}{1+z}(V|_D - V|_{TR}) \tag{4.27}$$

Equation (4.27) implies that there exists a subjective time preference rate, z, such that the net gain is zero. In this case, the monetary authority is indifferent between switching over to IP and executing the announced rule. This critical time preference rate, z^*, is given by

$$z^* = \frac{V|_D - V|_{TR}}{V|_{TR} - V|_{IP}} - 1 \qquad \Leftrightarrow \qquad N = 0 \tag{4.28}$$

A central bank with a rate of time preference larger than z^*, i.e. a monetary authority whose planning horizon is rather short, consequently expects $N > 0$. Correspondingly, a more long-run oriented central bank, $z < z^*$, expects $N < 0$, i.e. it would not switch over to the regime IP.

In our numerical example, the critical time preference rate z^* is 0.4903. The corresponding discount factor, $1/(1 + z^*)$, is then about 0.67 implying a central bank whose planning horizon is rather short. In the monetary economics literature, a basic assumption is that the subjective preference rate coincides with the long-run real interest rate.[14] The latter is typically chosen to be equal to 4% which is clearly below the critical subjective rate of time preference. Hence, such a central bank is farsighted and does not yield a net gain from inconsistent monetary policy. Assuming $z = 0.04$, the standard Taylor rule is consequently stable.[15]

[12] Alternatively, one can analyze the case where the central bank looses its reputation for *all* times when reneging once. However, the qualitative results remain unchanged.

[13] By assuming that the central bank looses its reputation for all times when deviating once from the announcement, the total gain resulting from IP would be given by

$$N' = B - C' = (V|_{TR} - V|_{IP}) - \sum_{i=1}^{\infty}\left(\frac{1}{1+z'}\right)^i (V|_D - V|_{TR})$$
$$\Leftrightarrow \quad N' = (V|_{TR} - V|_{IP}) - \frac{1}{z'}(V|_D - V|_{TR})$$

[14] As already mentioned, the social loss function (4.3) can be derived by a second order approximation of the household's utility function. Hence, the discount factors of the central bank and the households must coincide. Further note that when assuming a zero-inflation steady state, the real interest rate is equal to its

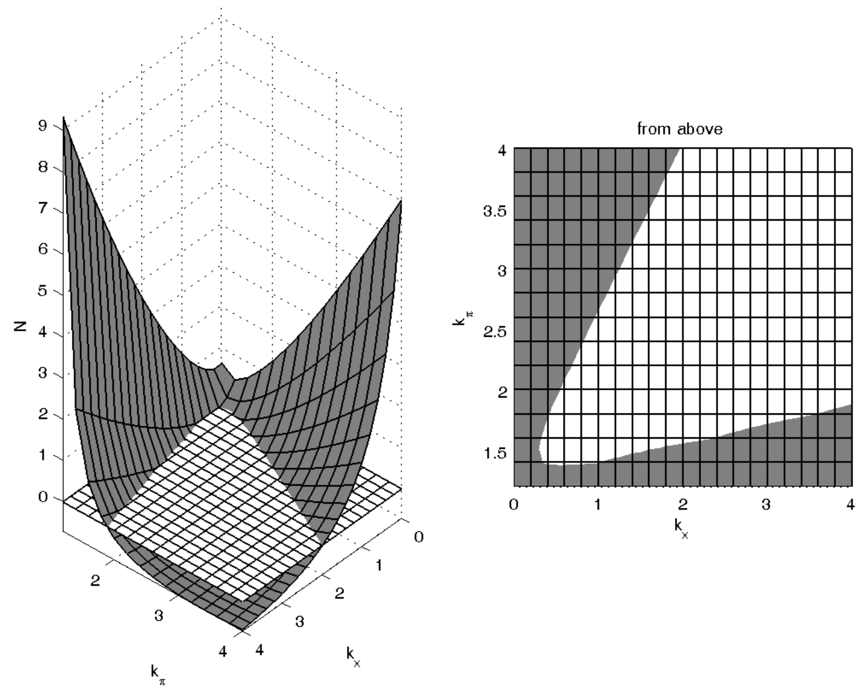

Figure 4.2: *Stable and unstable simple rules*

Figure 4.2 illustrates the net gain resulting from the deviation from the announced simple rule for different combinations of Taylor rule coefficients. The white shaded area indicates the zero plane. The intersection of this area and the net gain function consequently delivers the specific k_π/k_x-combinations which result in $N = 0$. This implies that the k_π/k_x-combinations within the white area on the right-hand side of Figure 4.2 deliver $N < 0$ since the cost exceeds the benefit of inconsistent policy. These rules are consequently time-consistent.[16] The limit case $N = 0$ just holds for the boundary of this area. It can moreover be observed from Figure 4.2 that a Taylor rule with $k_x = 0$ is never stable given our assumptions.

As in Barro and Gordon (1983a), there exists a continuum of reputational equilibria where the central bank has no incentive to deviate from the announced monetary policy. The monetary authority will consequently not switch over to inconsistent

nominal counterpart in the long-run.

[15] Note however that this result crucially depends on the calibration of the applied model. More precisely, the standard Taylor rule becomes unstable when assuming a lower weight on the output gap in the social loss function, λ.

[16] Remark: When disregarding the Taylor principle, i.e. by allowing $k_\pi < 0$, we moreover obtain a second continuum of stable simple rules. This is a plausible result since the social loss under TR (4.18) is a function in k_π of fourth order implying that for a given k_x there can exist up to four different real-valued solutions of k_π.

policy. Announcing such a rule is necessarily credible. The next step is to find an optimal stable interest rate rule.

Since the policy maker follows a Taylor rule – satisfying the Taylor principle and $k_x > 0$ – the monetary authority has to control for two parameters, k_π and k_x. In contrast to the Kydland/Prescott-Barro/Gordon approach where the central bank can directly control for the inflation rate, the optimal stable policy must now be determined in a three-dimensional space. Moreover, the optimal choice in Barro and Gordon (1983a) is a point in the intersection of the functions B and C since it minimizes the social loss. In our approach, the social loss resulting from the k_π/k_x-combinations implying $N = 0$ can however be improved when moving into the stable area.

For illustrating this issue, we will fix one Taylor coefficient for the moment in order to obtain a two-dimensional decision problem. Figure 4.3 illustrates the corresponding partial social loss function under TR (dashed lines) and the net gain resulting from inconsistent monetary policy (solid lines) when holding the Taylor rule coefficient on the output gap constant.[17] The figure indicates that under constant k_x there always exists a coefficient on inflation such that the resulting social loss is optimal. These (restricted) optima are denoted with a black dot. Figure 4.3 moreover shows that the k_π/k_x-combinations which result in $N = 0$ can be enhanced as they do not yield an optimal loss for given k_x.

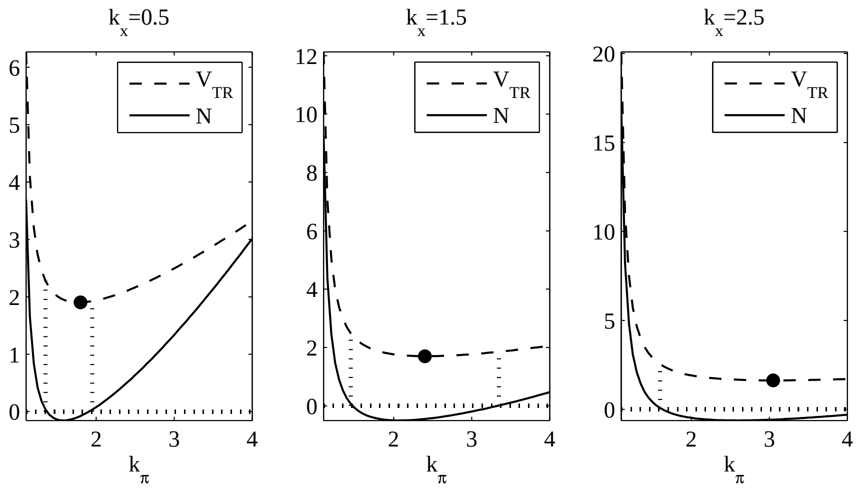

Figure 4.3: *The net gain N and the social loss under TR for different Taylor rule coefficients*

For instance, the combination $k_x = 0.5$ and $k_\pi = 1.35$ results in $N = 0$. However, this combination of Taylor rule coefficients is not optimal as the social loss can be enhanced when increasing the Taylor rule coefficient on inflation up to 1.8. The latter combination is *within* the stable area. This turns out to be a general result

[17] When holding k_π constant, we obtain a totally equivalent outcome.

since all (restricted) optima are within the stable area and not in the intersection of B and C. By contrast, the optimal policy choice in Barro and Gordon (1983a) is in the intersection of cost and benefit resulting from inconsistent monetary policy. Furthermore, Figure 4.3 indicates that the larger the Taylor rule coefficient, k_x, the larger is the second one, k_π, in the optimum. This result also holds vice versa when k_π is kept constant.

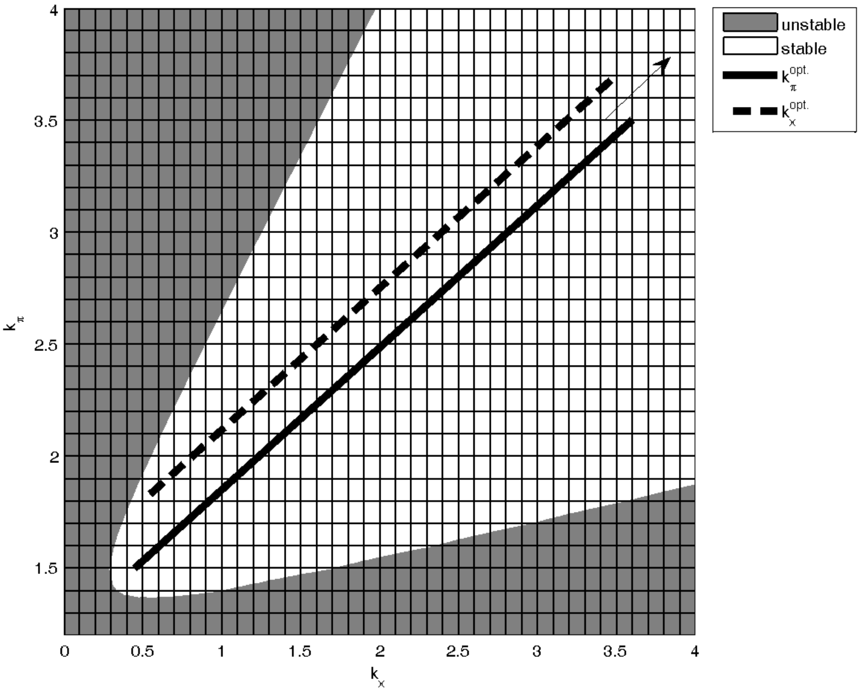

Figure 4.4: *Optimal Taylor rule coefficients*

Figure 4.4 depicts these optimal coefficients, $k_\pi^{opt.}$ and $k_x^{opt.}$, when respectively taking k_x and k_π as given. It can directly be observed that the corresponding lines of partial optima do not have an intersection. Consequently, there does not exist a globally optimal choice of Taylor rule parameters when both coefficients are variable. Since the loss decreases in both coefficients (cf. Figure 4.3), the minimal loss is obtained in the limit case $k_\pi \rightarrow \infty$ and $k_x \rightarrow \infty$. In Figure 4.4, this fact is indicated with a black arrow.

All in all, the unsatisfactory feature that there exists a multiplicity of stable monetary policy rules remains. However, Taylor rule coefficients resulting in $N = 0$ can be improved when moving into the stable area which contrasts with Barro and Gordon (1983a). Moreover, there does not exist a globally optimal time-consistent Taylor rule.

4.3.5 Extensions

For checking the robustness of the previous results, we will now turn to a monetary authority which is also concerned about stabilizing the interest rate as in Svensson (2000). The extended social loss function then looks as follows

$$V' = (\pi - \pi^T)^2 + \lambda(x - x^T)^2 + \gamma(i - i^T)^2 \tag{4.29}$$

with $\lambda > \gamma > 0$. Although (4.29) cannot be derived from the household's utility function in the canonical New Keynesian framework, Kobayashi (2008) and Teranishi (2008) show within a framework where the financial sector has a non-trivial role, the social loss function should include a positive weight on a financial variable. We set γ to 0.05.

The proceeding for the derivation of the social loss for the different policy designs is equivalent to that in the previous sections.[18]

The Impact of Stabilizing the Interest Rate

The numerical evaluation of the different policy regimes in the case of the cost-push shock yields

$$V|_D' = 6.5586 > V|_{TR}' = 2.1044 > V|_{IP}' = 1.6987 \tag{4.30}$$

resulting in a critical rate of time preference equal to 9.9790. Consequently, the standard Taylor rule is only unstable when assuming very myopic considerations of the central bank. Under our standard calibration including $z = 0.04$, the standard Taylor rule however remains stable when extending the social loss function.

Figure 4.5 shows the net gain resulting from the deviation of the announced Taylor rule for different k_π/k_x-combinations. The qualitative results remain unchanged in comparison to the case with $\gamma = 0$. However, it is worth mentioning that the stable area, i.e. the set of k_π/k_x-combinations that do not cause any incentive for the monetary authority to switch over to inconsistent policy, becomes *larger* when assuming $\gamma > 0$. This implies that the reputation of the central bank naturally improves if the policy maker is also concerned about stabilizing the interest rate. The rationale is that the social loss under discretionary monetary policy relatively increases more than those under inconsistent policy and under the Taylor rule. As a result, the cost of inconsistent policy, C, increases more than the benefit, B.

In contrast to the case $\gamma = 0$, a Taylor rule with $k_x = 0$ may be time-consistent if the Taylor rule coefficient on inflation is rather small.

[18] See the Appendix for the different social losses in the different policy regimes with $\gamma > 0$ and the respective derivations.

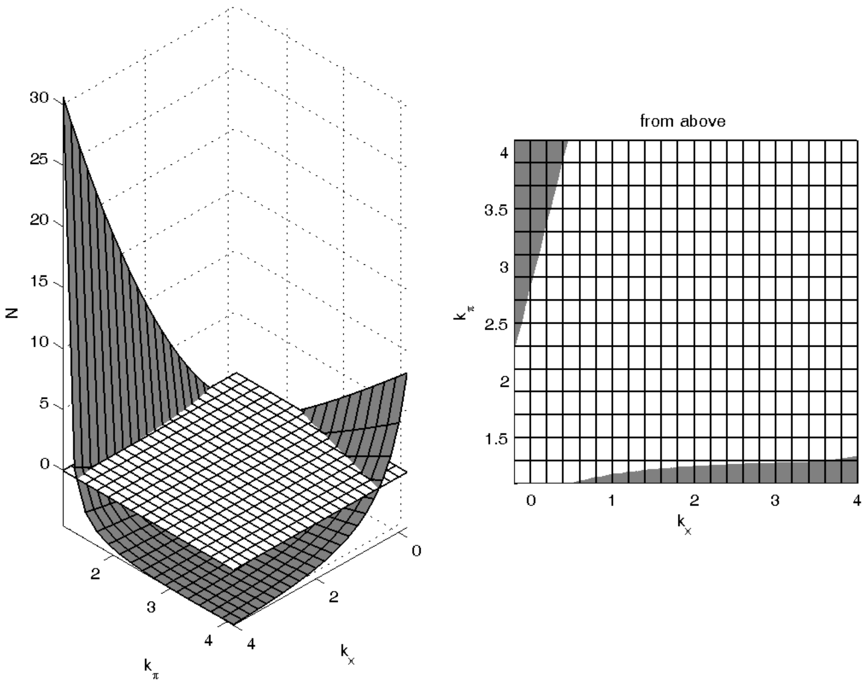

Figure 4.5: *Stable and unstable simple rules with $\gamma > 0$*

Simultaneous Supply and Demand Shocks

As already mentioned and as shown in the Appendix, the demand shock can be interpreted as a shock to aggregate technology which is typically assumed to be expansionary ($\psi > 0$). In our notation this implies $\varepsilon_1 < 0$ since a technology shock causes the natural level, y^*, to increase more than the current one, y. This in turn leads to a decline in the output gap, $x \equiv y - y^*$.

It is well-known that a pure demand shock can be totally compensated by discretionary monetary policy in the case $\gamma = 0$. This can be directly observed from the IS curve (4.1).[19] Hence, we will analyze simultaneous supply and demand shocks in the following. For the sake of simplicity, we will also normalize the impact of the demand shock to one, i.e. $\varepsilon_1 = -1$.

Then, the numerical evaluation of the different policy regimes yields

$$V|'_D = 6.4250 > V|'_{TR} = 2.7489 > V|'_{IP} = 1.6992 \tag{4.31}$$

implying a critical subjective discount factor equal to 2.5020. Hence, the standard Taylor rule still remains stable when additionally considering an technological inno-

[19]In this specific case, the discretionary monetary policy would obviously be the first best solution.

vation.

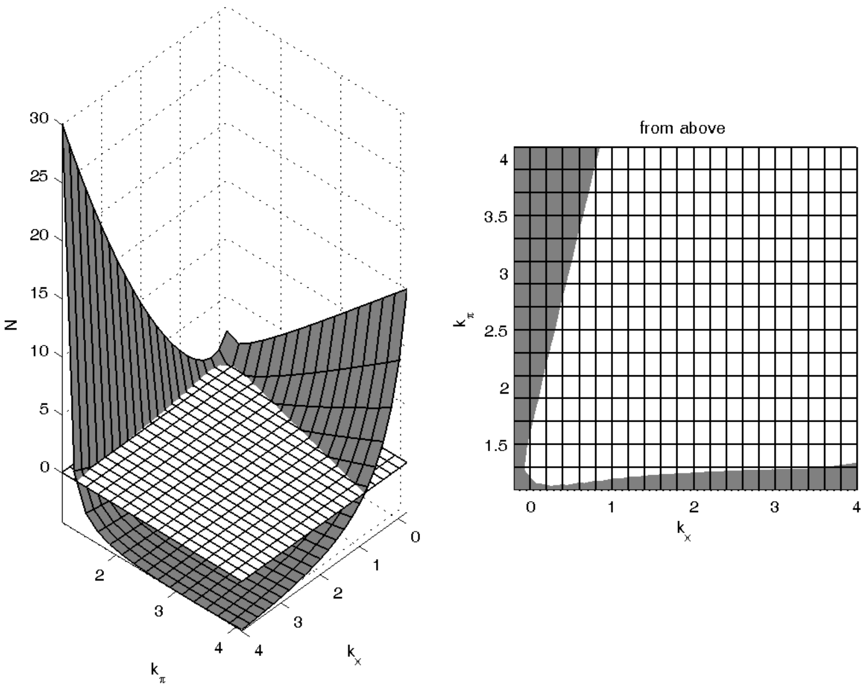

Figure 4.6: *Stable and unstable simple rules – simultaneous supply and demand shocks ($\varepsilon_1 < 0$ and $\varepsilon_2 > 0$)*

Figure 4.6 shows the net gain resulting from a deviation from the announced Taylor rule for a continuum of k_π/k_x-combinations. The continuum of stable Taylor rules now becomes smaller when considering the contractionary demand shock (cf. Figure 4.5).[20] The rationale is that the social loss under the commitment strategy increases relative to those under inconsistent and discretionary policy. Consequently, the cost resulting from the loss in the central bank's reputation declines leading to an increasing incentive to switch over to inconsistent policy.

4.4 Conclusion

We implement the Kydland/Prescott-Barro/Gordon approach in a static approximation of the canonical New Keynesian model. Within this framework, we are able to discuss both the commitment vs. discretion debate of the New Keynesian literature and the time-inconsistency problem of Barro and Gordon (1983a,b) in a unified framework.

[20] As expected, the stable area becomes larger when assuming the demand shock to be expansionary, too, i.e. $\varepsilon_1 = \varepsilon_2 = 1$.

We first show that commitment strategies can be advantageous to discretionary monetary policy. Second, we show that these policy rules cause the monetary authority to deviate from their announcements since the re-optimization yields a welfare gain. By assuming a long-run planning horizon of the central bank and that the monetary authority looses its reputation when switching over to inconsistent policy, we find a continuum of stable interest rate rules of Taylor-type. In contrast to the Kydland/Prescott-Barro/Gordon approach, implementing a monetary rule such that the cost and benefit resulting from inconsistent policy coincide, is *not* optimal. Instead, the solution can be enhanced by moving into the stable area where the net gain of inconsistent monetary policy behavior is negative.

By introducing an additional term in the social loss function concerning interest rate stabilization, the continuum of stable Taylor rules becomes larger. This implies that the reputation of the monetary authority naturally improves when it is also concerned about stabilizing the interest rate. Third, we find that under a standard calibration including a time preference rate equal to the long-run interest rate, the standard Taylor rule is time-consistent for the cost-push shock as well as for simultaneous supply and demand shocks. Fourth, there does not exist a stable Taylor rule in explicit form which minimizes the social loss.

Appendix A: Derivation of the Demand Shock

For production firms (intermediate good producers) need only one input factor, labor, which is denoted by N. The production function is then simply given by

$$Y = \Psi N \tag{A.4.1}$$

where Y is output and Ψ represents a shock to aggregate productivity.[21]

Under flexible prices the marginal costs, MC, are constant. They are obtained by cost minimization

$$MC = \frac{W}{\Psi} = const. \qquad \Leftrightarrow \qquad w = \psi \tag{A.4.2}$$

The Euler consumption equation and the labor supply equation follow from the utility maximization of the representative household.

$$y = a - br \tag{A.4.3}$$

$$w = \eta n + \frac{1}{b} y \tag{A.4.4}$$

where η represents the Frisch elasticity of labor supply.

Subtracting the natural level from the Euler equation yields[22]

$$x \equiv y - y^* = a - br - y^* \tag{A.4.5}$$

Log-linearizing the production function (A.4.1) expressed in natural levels and inserting the resulting equation in (A.4.5) considering (A.4.2) and (A.4.4), yields

$$x = a - br - \frac{b + b\eta}{1 + b\eta}\psi \tag{A.4.6}$$

Since $\frac{b+b\eta}{1+b\eta} > 0$, a shock to aggregate technology can thus be interpreted as a contractionary demand shock. The economic intuition is that the natural level increases more to an expansionary shock to productivity than the distorted actual output level such that the difference – the output gap – decreases.

Appendix B: Social Losses with $\gamma > 0$ and $\varepsilon_1 \neq 0$ and $\varepsilon_2 \neq 0$

The modified loss function now contains an additional term concerning nominal interest rate stabilization.

$$V' = (\pi - \pi^T)^2 + \lambda(x - x^T)^2 + \gamma(i - i^T)^2 \tag{A.4.7}$$

[21] In the following, capital letters denote variables in non-log-linearized form, while small letters denote log-linearized variables.

[22] In the following, an asterisk denotes a natural variables, i.e. the realization of a variable without any nominal or real rigidity.

Simple Rules

The proceeding for deriving the social loss is equivalent to that in the main text.

Since we analyze calibrated instead of optimal simple rules, private expectations are thus not altered by the modified loss function and still follow (4.15)

$$\pi^e|_{TR} = \pi^T + \frac{1+bk_x}{b(k_\pi - 1)}x^T \tag{A.4.8}$$

When combining (4.15) and the Phillips curve (4.2), we obtain the solution path of the output gap and the inflation rate.

$$x|'_{TR} = \frac{1}{\alpha}\varepsilon_1 - \frac{bk_\pi}{\alpha}\varepsilon_2 \tag{A.4.9}$$

$$\pi|'_{TR} = \pi^T + \frac{1+bk_x}{b(k_\pi - 1)}x^T + \frac{\delta}{\alpha}\varepsilon_1 + \frac{1+bk_x}{\alpha}\varepsilon_2 \tag{A.4.10}$$

The additional demand shock causes an upward-pressure on both inflation and the output gap.

Finally, we need the solution for the nominal interest rate. Therefore, we insert (A.4.9) and (A.4.10) in the Taylor rule (4.11).

$$i|'_{TR} = i^T + \frac{k_\pi + bk_x}{b(k_\pi - 1)}x^T + \frac{\delta k_\pi + k_x}{1+b(k_x + k_\pi\delta)}\varepsilon_1 + \frac{k_\pi}{1+b(k_x+k_\pi\delta)}\varepsilon_2 \tag{A.4.11}$$

In order to obtain the social loss under the policy regime TR for arbitrary coefficients k_π and k_x, we insert the solutions of the output gap, inflation, and the interest rate in the welfare function (4.4).

$$\begin{aligned} V|'_{TR} = &\left[\frac{1+bk_x}{b(k_\pi - 1)}x^T + \frac{\delta}{\alpha}\varepsilon_1 + \frac{1+bk_x}{\alpha}\varepsilon_2\right]^2 + \lambda\left[\frac{1}{\alpha}\varepsilon_1 - \frac{bk_\pi}{\alpha}\varepsilon_2 - x^T\right]^2 \\ &+ \gamma\left[\frac{k_\pi + bk_x}{b(k_\pi - 1)}x^T + \frac{\delta k_\pi + k_x}{1+b(k_x+k_\pi\delta)}\varepsilon_1 + \frac{k_\pi}{1+b(k_x+k_\pi\delta)}\varepsilon_2\right]^2 \end{aligned} \tag{A.4.12}$$

Naturally, the latter expression simplifies to (4.18), if $\gamma = 0$ and $\varepsilon_1 = 0$.

Optimal Discretionary Monetary Policy

In contrast to the case where the demand shock is absent, the monetary authority must now consider the IS curve in the optimization approach.

Inserting the Phillips curve and the Euler consumption equation in the social loss function and optimizing the resulting expression with respect to the output gap delivers the following first-order condition

$$\lambda(x - x^T) + \delta(\pi - \pi^T) - \frac{\gamma}{b}(i - i^T) = 0 \tag{A.4.13}$$

By inserting this expression considering (4.1) in the Phillips curve (4.2) and taking rational private expectations, we obtain

$$\pi^e|_D' = \pi^T + \frac{\lambda b^2 + \gamma}{b(\delta b - \gamma)} x^T \tag{A.4.14}$$

The solution of the output gap is then given by

$$\pi|_D' = \pi^T + \frac{\lambda b^2 + \gamma}{b(b\delta - \gamma)} x^T + \frac{\gamma\delta}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_1 + \frac{\lambda b^2 + \gamma}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_2 \tag{A.4.15}$$

Inserting (A.4.14) and (A.4.15) in the Phillips curve, yields the solution of the output gap

$$x|_D' = \frac{\gamma}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_1 - \frac{\delta b^2}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_2 \tag{A.4.16}$$

The solution of the nominal interest rate is finally obtained by inserting (A.4.15) and (A.4.16) in (A.4.13)

$$i = i^T + \frac{\delta + b\lambda}{b\delta - \gamma} x^T + \frac{b(\lambda + \delta^2)}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_1 + \frac{\delta b}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_2 \tag{A.4.17}$$

Inconsistent Monetary Policy

The proceeding is totally analogous to the main text. Therefore, we will only present the resulting solutions of the output gap, the inflation rate, and the nominal interest rate. They are given by

$$\begin{aligned}
\pi|_{IP}' - \pi^T &= \frac{(\lambda b^2 + \gamma)(1 + b(k_x + \delta k_\pi)) + \delta b^2(\gamma k_x - \lambda b)}{(b^2(\lambda + \delta^2) + \gamma) b(k_\pi - 1)} x^T \\
&\quad + \frac{\gamma\delta}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_1 + \frac{\lambda b^2 + \gamma}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_2 &\text{(A.4.18)} \\
x|_{IP}' - x^T &= \frac{\gamma(1 + bk_x) - \delta b(1 + b(k_x + \delta k_\pi) - \delta b)}{(k_\pi - 1)(b^2(\lambda + \delta^2) + \gamma)} x^T \\
&\quad + \frac{\gamma}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_1 - \frac{\delta b^2}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_2 &\text{(A.4.19)} \\
i|_{IP} - i^T &= \frac{\lambda b(1 + bk_x) + \delta(1 + b(k_x + \delta(k_\pi + bk_x)))}{(k_\pi - 1)(b^2(\lambda + \delta^2) + \gamma)} x^T \\
&\quad + \frac{b(\lambda + \delta^2)}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_1 + \frac{\delta b}{b^2(\lambda + \delta^2) + \gamma} \varepsilon_2 &\text{(A.4.20)}
\end{aligned}$$

5 Fiscal Stimulus in a Business Cycle Model with Firm Entry

5.1 Introduction

In order to fight the recessionary impacts of the recent financial crisis, governments throughout the globe have passed large fiscal packages and thereby triggered a debate about the effectiveness of government spending in stimulating economic activity.

In this context Romer and Bernstein (2009) evaluate the impacts of the US fiscal package of January 2009 and find a multiplier significantly larger than one. However, several authors challenge this finding. Cogan et al. (2010) and Cwik and Wieland (2009) respectively employ empirically estimated models for the US and Euro economy [Smets and Wouters (2007, 2003)] also incorporating rule-of-thumb consumers and report multipliers less than one. Uhlig (2010) emphasizes the role of distortionary taxation for the effectiveness of fiscal stimuli. He shows that an increase in government consumption which is financed not only by debt but partly by distortionary labor taxes leads to a short-run boom in output but comes at the cost of an output reduction later on. Faia, Lechthaler, and Merkl (2010b) and Campolmi, Faia, and Winkler (2010) demonstrate that a pure demand stimulus leads to very small (or even negative) multipliers in models with frictional labor markets. Moreover, both studies emphasize that other forms of fiscal stimuli such as hiring subsidies or income tax cuts are much more effective in boosting output and employment.

All these contributions analyze the impacts of fiscal stimuli on standard measures of economic activity (GDP, employment, investment) but neglect their impact on the extensive margin, i.e. the mass of incumbent and new products (or: firms) in the market.[1] However, a recent literature highlights the role of an endogenous mass of firms as an important propagation and amplification mechanism for business cycle fluctuations.[2] Bilbiie, Ghironi, and Melitz (2007a) and Bergin and Corsetti (2008) respectively demonstrate that technological innovations and shocks to monetary policy are amplified by endogenizing the extensive margin. With respect to fiscal interventions, a substantial pro-cyclical behavior of the mass of firms may help to explain how fiscal stimuli generate large and persistent business cycle fluctuations.

[1] Remark: As standard in the macroeconomics literature, there is a one-to-one identification between a firm and a product. We will thus use the latter expressions synonymously.

[2] Among others, Devereux, Head, and Lapham (1996), Bergin and Corsetti (2008), and Totzek (2010) show that GDP is highly correlated with the number of producing firms.

In particular, this amplification effect potentially gives rise to larger multipliers.[3]

The aim of this chapter[4] is thus twofold. First, we explore the impacts of different fiscal stimuli on firm entry applying a Real Business Cycle model with firm entry which we estimate for the US using Bayesian techniques. Second, we calculate fiscal multipliers for both our baseline model with an endogenous mass of firms and for the standard case of a constant extensive margin. This enables us to investigate whether a changing mass of firms alters the effectiveness of fiscal stimuli. Our framework moreover allows for a closer examination of investment decisions – and crowding-out/in effects of fiscal interventions – since we can distinguish between investments in physical capital and those in new products. A further advantage of this kind of models is that profit taxation is not lump-sum. This allows a broader base for fiscal policy analysis.

Note that the aim of this chapter is however *not* to calculate fiscal multipliers of the American Recovery and Reinvestment Act (ARRA) since we do not apply a large scale DSGE model with several nominal and real frictions as for instance in Cogan et al. (2010) or Cwik and Wieland (2009). Instead, we apply a rather simple framework and focus on the qualitative and quantitative differences to the standard RBC model. More precisely, we apply a variant of the model outlined in Bilbiie, Ghironi, and Melitz (2007a) with endogenous firm entry and capital in production. We consider six forms of fiscal stimuli: (i) a standard increase in government spending[5] (a pure demand stimulus), (ii) a consumption tax cut, (iii) a cut in labor income taxes, (iv) a cut in capital income taxes, (v) a cut in dividend income taxes, and (vi) a unified cut in dividend and capital taxes. Thereby, we first assume that all fiscal stimuli are financed by lump-sum taxes. Thereafter, we reassess the results for the pure demand stimulus considering that the increase in government consumption is financed by different schemes of distortionary tax financing.

Our main findings are as follows. We demonstrate that the extensive margin can indeed act as an accelerator for the impacts of fiscal stimuli. However, we find that the quantitative reaction of the extensive margin – in particular, the sign of the reaction – crucially depends on the form of a fiscal stimulus. Moreover, we find that

[3] Other well-known mechanisms to generate larger fiscal multipliers are for instance the introduction of sticky prices [cf. Linnemann and Schabert (2003)], rule-of-thumb consumers [cf. Galí, López-Salido, and Vallès (2007)] or backward indexation of prices [cf. Chari et al. (2009)]. We however want to analyze the *pure* effects of firm entry on fiscal multipliers.

[4] For a different version of this chapter see "Fiscal Stimulus in a Model with Endogenous Firm Entry", (with R. C. Winkler) November 2010, Munich Personal RePEc Archive (MPRA) Paper No. 26829.

[5] As standard in the literature, we assume that the government only purchases consumption goods [see amongst others Smets and Wouters (2007, 2003), Galí, López-Salido, and Vallès (2007) or Linnemann and Schabert (2003)]. Therefore, we will use the expressions "government spending" and "government consumption" synonymously. Alternatively, Leeper, Walker, and Yang (2010) consider government investment or Cavallo (2005), Gomes (2009) or Leeper, Walker, and Yang (2010) assume that governments employ workers to produce goods used for government consumption or government investment. However, these approaches do not generate larger multiplier. Instead, they often generate negative short-run multipliers before they turn positive in the longer-run.

if in response to a fiscal expansion the mass of firms increases, fiscal multipliers are amplified. In this case, two expansionary effects arise. First, an increasing extensive margin has a positive impact on goods production via the 'love of variety effect' [see Benassy (1996) and Bergin and Corsetti (2008)].[6] Second, households have to invest in start-ups to create new firms. Additional investments in turn boost GDP. When compared to the standard RBC model – with a constant extensive margin – the multipliers are significantly larger. If, by contrast, the mass of firms decreases, the extensive margin dampens the impacts of fiscal stimuli on economic activity. The drop in new firm investment then represents an additional crowding-out effect. In comparison with the standard RBC model, the resulting multipliers are then significantly smaller.

With respect to the different fiscal packages, our analysis shows that the reaction of the extensive margin in response to an increase in government consumption turns out to be ambiguous. In line with this finding, Lewis (2009b) points out that the mass of firms only reacts expansionary if the fiscal demand shock is sufficiently persistent.[7] The economic rationale is that only under highly persistent shocks potential firms expect future profit opportunities which cover the entry cost and consequently enter the market.

We extend this analysis by demonstrating that the ambiguous impact of government consumption shocks on the mass of firms is not only driven by the shock persistence but by the combination of the latter with the labor supply elasticity. Furthermore, we show that the source of government financing is a crucial dimension, too. The economic intuition why the reaction of the mass of product varieties may turn negative when the labor supply elasticity is low is as follows. Suppose labor is the only input in production and is supplied totally inelastic. In an RBC model with a fixed mass of producers, an increase in government consumption consequently then causes a complete crowding-out of private consumption. In the entry model, however, households can reallocate their labor force between working in the manufacturing sector and creating new products.[8] Households are then able to dampen the drop in private consumption by increasing hours worked in the manufacturing sector and decrease hours worked for product creation. The mass of firms consequently declines when labor supply is sufficiently inelastic.

The impulse response analysis based on the estimated mean of the parameters shows a decrease in the mass of firms in response to an increase in government consumption. The additional crowding-out effect pushes the multiplier below that of the RBC

[6] This effect directly follows from the aggregation of intermediate goods and implies that an increase in the mass of firms has ceteris paribus a positive impact on aggregate production.

[7] Lewis (2009b) extends the sticky price framework of Bilbiie, Ghironi, and Melitz (2007b) to allow for government spending shocks. The optimal fiscal policy in a framework with firm entry and flexible prices is derived in Chugh and Ghironi (2009).

[8] Remark: As in amongst others Bilbiie, Ghironi, and Melitz (2007b), we assume that labor is needed to create new products.

model with a constant mass of firms. This is particularly true when considering the case of an increase in government consumption financed by distortionary income taxation. In line with the findings of Uhlig (2010) the long-run fiscal multipliers then become significantly negative. Similar results are found for the case of a demand stimulus through a cut in consumption taxes.

Due to the fact that fiscal demand stimuli may cause a crowding-out not only of investment in physical capital and consumption but also of investment in new firms, we show that these interventions lead to small fiscal multipliers in the applied framework.[9] By contrast, the multipliers of labor and dividend tax cuts are significantly larger.[10] The reason is that in these cases we find a crowding-in of private consumption, of investment in existing capital, and of investment in product creation. The latter effect in turn leads to an increasing mass of firms. Although the multiplier of a cut in capital taxes is also close to one, this policy comes at the cost of a crowding-out in new firm investment and thus of a decrease in the mass of firms.

Finally, this study is – to the best of our knowledge – the first that conducts a Bayesian estimation of a DSGE model with firm entry incorporating several structural shocks. In a complementary study, Lewis and Poilly (2010) estimate a DSGE model with firm entry by using a VAR minimum distance approach. They apply a framework with several nominal and real frictions but focus on a single shock to monetary policy.

The remainder of this chapter is as follows. Section 2 presents the model. In Section 3, the results of the Bayesian estimation are presented. In Section 4, we discuss the estimated responses to an increase in government consumption. The fiscal multipliers of six fiscal packages, all financed with lump-sum taxes, are discussed in Section 5. In Section 6, we analyze a pure demand stimulus that is financed by raising distortionary taxes. Section 7 concludes.

[9] Note that we apply an RBC framework. A corresponding "traditional" approach would be the famous AD/AS-model with flexible prices and wages of a closed economy [neoclassical variant, see amongst others Wohltmann (2007, Ch. 6)]. In this framework, an increase in government spending has no effects on output, at all, since it does not affect the supply side of production. By contrast, an increase in government spending financed by lump-sum taxation leads to an increase in labor supply in an RBC framework caused by the negative wealth effect [cf. Baxter and King (1993)]. The wealth effect works as follows. Since the increase in government spending is financed by lump-sum taxation, it represents a negative effect on the total income of households. The households consequently decrease their consumption expenditures and increase their labor supply to compensate for the additional tax expenditures. This increase in labor supply in turn leads to an expansionary reaction of production. In contrast to traditional approaches, this wealth effect is thus *not* a direct but an indirect effect.

[10] This is not a very surprising result since these taxes are distortionary and have a direct impact on the supply side of the economy. Moreover, the cuts in these tax rates are financed by lump-sum taxation which additional leads to an expansionary reaction of production via the negative wealth effect. The result that tax cuts which affect the supply of production leads to larger multipliers than an increase in government spending is already known from the neoclassical variant of the AD/AS-model, too. This is for instance the case when analyzing a cut in ancillary labor costs. This tax cut has positive effects on GDP while – as already mentioned – an increase in government spending has only allocational effects in such an environment [cf. Wohltmann (2007, Ch.6).]

5.2 The Model

We apply the entry model of Bilbiie, Ghironi, and Melitz (2007a) with capital in production.[11] The economy consists of final goods producers (or: bundlers), intermediate goods producers (or: manufacturing firms), new product creators, the government, and households. Each manufacturing firm employs labor and capital to produce a single differentiated intermediate good in a monopolistic competitive market under flexible prices.[12] New product creators use labor to invent new varieties of intermediate goods. Notice that new product creation is equivalent to the production of a new manufacturing firm due to the common assumption of a one-to-one identification between a manufacturing firm and an intermediate good. Final goods producers bundle the intermediate goods to a homogeneous final good used for private and fiscal consumption as well as for investment in physical capital. Households consume, invest in physical capital, hold government bonds, and hold shares of the stock of intermediate goods producers. Moreover, households supply labor to the manufacturing and the product creation sector. Government consumption is financed by issuing bonds, by collecting lump-sum taxes, by levying taxes on consumption purchases, and by levying income taxes on labor, capital, and dividends. The model structure is depicted in Figure 5.1.

5.2.1 Final Goods Producers

Final goods producers buy the differentiated intermediate goods or varieties, $y_t(\omega)$, bundle them to a homogeneous final good, Y_t^C, and sell it to households and to the government under perfectly competitive conditions. A final goods producer maximizes his profits, $Y_t^C P_t - \int_0^{N_t} p_t(\omega) y_t(\omega) d\omega$, subjected to the following CES production function $Y_t^C \equiv \left(\int_0^{N_t} y_t(\omega)^{(\zeta_t - 1)/\zeta_t} d\omega \right)^{\zeta_t/(\zeta_t - 1)}$, where P_t is the price of the final good, $p_t(\omega)$, is the price of variety ω, and ζ_t is the time-varying elasticity between the intermediate goods. The latter follows an exogenous AR(1) process: $\log \zeta_t = (1 - \rho_\zeta) \log \zeta + \rho_\zeta \log \zeta_{t-1} + \varepsilon_t^\zeta$, where ε_t^ζ is white noise and $0 \leq \rho_\zeta < 1$.[13] N_t denotes the non-stationary mass of firms operating in the economy at t. The first-order condition for profit maximization yields the demand function for variety ω which is given by $y_t(\omega) = \rho_t(\omega)^{-\zeta_t} Y_t^C$, where $\rho_t(\omega) \equiv p_t(\omega)/P_t$ is the relative

[11] Bilbiie, Ghironi, and Melitz (2007a) present three specifications of a model for a closed and cashless economy with endogenous firm entry: (i) the baseline model without capital, (ii) a model with capital in production, and (iii) a model with capital in production and in product creation. Of course, the model specifications with capital perform better by fitting the empirically observed second moments. However, the model with capital in both production and in product creation requires a highly implausible calibration including a 50% depreciation rate to ensure stability and non-oscillating impulse responses. We therefore restrict our analysis to the second model specification, i.e. a model with endogenous firm entry and capital in production.

[12] Bilbiie, Ghironi, and Melitz (2007b) extend the framework of Bilbiie, Ghironi, and Melitz (2007a) by introducing sticky prices. Since we do not want to discuss the interdependency between fiscal and monetary interventions, we apply the pure RBC version. See amongst others Linnemann and Schabert (2003) for an investigation of this topic in the standard New Keynesian model.

[13] In the following, a variable without a time index denotes the respective steady state value.

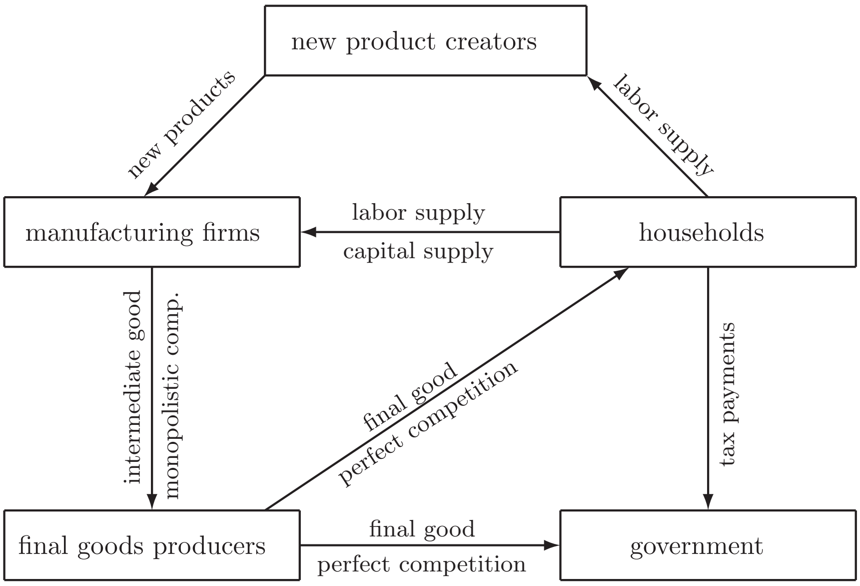

Figure 5.1: *Model structure*

price of variety ω and $P_t = \left(\int_0^{N_t} p_t(\omega)^{1-\zeta_t} d\omega\right)^{1/(1-\zeta_t)}$ is the resulting price index. Since there is no heterogeneity in this framework, we refer to symmetry across firms, implying $y_t(\omega) = y_t$, $p_t(\omega) = p_t$, $\rho_t(\omega) = \rho_t$. The aggregate amount of intermediate goods (or: aggregate demand) is obtained by solving the CES technology:

$$Y_t^C = N_t^{\frac{\zeta_t}{\zeta_t - 1}} y_t. \tag{5.1}$$

The price index can be written as $P_t = N_t^{1/(1-\zeta_t)} p_t$ implying $\rho_t = N_t^{1/(\zeta_t - 1)}$.

5.2.2 Intermediate Goods Producers

Each intermediate goods producer is a monopolistic supplier of product ω. A firm uses the amount l_t of labor, the amount k_{t-1} of physical capital and the constant returns to scale technology

$$y_t = z_t l_t^\alpha k_{t-1}^{1-\alpha} \tag{5.2}$$

to produce the intermediate good, y_t. z_t is total factor productivity (or: an aggregate technology shock[14]) which follows the process: $\log z_t = (1 - \rho_z) \log z + \rho_z \log z_{t-1} + \varepsilon_t^z$, where ε_t^z is white noise. $\alpha \in (0, 1)$ denotes the share of labor in production. The firm takes the factor prices w_t and r_t^K as given. The marginal costs, $mc_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} w_t^\alpha (r_t^K)^{1-\alpha}/z_t$, are identical for all firms implying a symmetric equilibrium.[15]

[14] In contrast to Chapter 3, Bilbiie, Ghironi, and Melitz (2007a) assume firms to be homogeneous such that we do not have to distinguish between individual and aggregate productivity.

[15] See Appendix for a proof.

The firm chooses the real price, ρ_t, in order to maximize profits, $d_t = (\rho_t - mc_t)y_t$, subjected to the demand function $y_t = \rho_t^{-\zeta_t} Y_t^C$. The optimization yields

$$\rho_t = \frac{\zeta_t}{\zeta_t - 1} mc_t\,. \tag{5.3}$$

In the absence of shocks to the intratemporal elasticity between intermediate goods, the real price is set as a constant mark-up over real marginal costs.

Factor demands are obtained by cost minimization and read as[16]

$$w_t = \alpha mc_t \frac{y_t}{l_t} = \alpha \frac{\zeta_t - 1}{\zeta_t} \frac{Y_t^C}{L_t^C}\,, \tag{5.4}$$

$$r_t^K = (1-\alpha) mc_t \frac{y_t}{k_{t-1}} = (1-\alpha) \frac{\zeta_t - 1}{\zeta_t} \frac{Y_t^C}{K_{t-1}}\,, \tag{5.5}$$

where $L_t^C = N_t l_t$ are hours worked in the manufacturing sector and $K_{t-1} = N_t k_{t-1}$ is aggregate demand for capital.

Using (5.3) and $\rho_t = N_t^{1/(\zeta_t - 1)}$, the profits of a firm can be expressed as

$$d_t = \left(1 - \frac{\zeta_t - 1}{\zeta_t}\right) \frac{Y_t^C}{N_t} = \frac{1}{\zeta_t} \frac{Y_t^C}{N_t}\,. \tag{5.6}$$

5.2.3 New Product Creators

Firms in this perfectly competitive sector create new products amounting to, $N_{E,t}$, by using labor, L_t^E, and the technology $N_{E,t} = L_t^E / f_{E,t}$ in order to maximize their profits $v_t N_{E,t} - (w_t/z_t) L_t^E$. v_t denotes the real value of an operating firm in the intermediate goods sector which is equal to the discounted sum of all current and future profits. $1/f_{E,t}$ denotes a productivity shifter such that $f_{E,t}$ can also be interpreted as a time-varying entry cost that follows the exogenous AR(1) process: $\log f_{E,t} = (1 - \rho_{f_E}) \log f_E + \rho_{f_E} \log f_{E,t-1} + \varepsilon_t^{f_E}$, where $\varepsilon_t^{f_E}$ is white noise and $0 \leq \rho_{f_E} < 1$. The first-order condition for profit-maximization yields the free entry condition $v_t = (w_t/z_t) f_{E,t}$.

To capture the empirical finding that firm entries do not take place contemporaneously with GDP [see amongst others Devereux, Head, and Lapham (1996)], we assume a time-to-build lag in new product creation. As in Bilbiie, Ghironi, and Melitz (2007a), we assume, for the sake of simplicity, that the firm's death rate is exogenous.[17] The recursive law of motion of the extensive margin is then given by

$$N_t = (1-\delta)(N_{t-1} + N_{E,t-1})\,, \tag{5.7}$$

where $N_{E,t}$ is the mass of new firms and δ denotes the exogenous probability of exiting the market. Equation (5.7) states that a fraction, δ, of incumbent and new firms is hit by an exogenous death shock at the very end of any period.

[16] See Appendix for a proof.

[17] See Totzek (2010) or Chapter 3 for a New Keynesian framework where endogenous entries and exits are considered simultaneously.

5.2.4 Households

The economy is made up by a continuum of homogeneous households distributed over the unit interval. The representative household determines the amount of the final good for consumption, C_t, and for investment, I_t, its one-period real bond holdings, B_t, its share holdings, x_{t+1}, and its supply of hours worked, L_t, in order to maximize its expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \frac{\chi_t}{1+\eta} L_t^{1+\eta} \right) , \tag{5.8}$$

where $\beta \in (0,1)$ is the discount factor, $\eta > 0$ is the inverse of the labor supply elasticity, and $\chi_t > 0$ is a shock to the labor supply that follows an AR(1) process: $\log \chi_t = (1-\rho_\chi) \log \chi + \rho_\chi \log \chi_{t-1} + \varepsilon_t^\chi$, where ε_t^χ is white noise and $0 \leq \rho_\chi < 1$. The maximization of (5.8) is subjected to the household's period-by-period budget constraint

$$\begin{aligned} B_t - (1+r_{t-1})B_{t-1} + v_t(N_t + N_{E,t})x_{t+1} + (1+\tau_t^C)C_t + I_t + \tau_t = \\ (v_t + (1-\tau_t^d)d_t)x_t N_t + (1-\tau_t^L)w_t L_t + (1-\tau_t^K)(r_t^K - \delta^K)K_{t-1} + \delta^K K_{t-1} \, , \end{aligned} \tag{5.9}$$

the capital accumulation equation

$$K_t = (1-\delta^K)K_{t-1} + I_t \, , \tag{5.10}$$

and the dynamics of firm entry and exit described by equation (5.7). r_t and δ^K denote the real interest rate and the capital depreciation rate, respectively. The government collects lump-sum taxes, τ_t, and levies taxes on consumption, on labor income, $w_t L_t$, on capital income net of depreciation, $(r_t^K - \delta^K)K_{t-1}$, and on dividend income, $d_t x_t N_t$ where $x_t N_t$ denotes the share of firms in which a household has invested and d_t are per period profits. The respective tax rates are τ_t^C, τ_t^L, τ_t^K, and τ_t^d.[18] The household uses its net income for consumption, investment in physical capital, investment in government bonds, and investment in shares of incumbent firms and entrants in the intermediate goods sector, $v_t(N_t + N_{E,t})x_{t+1}$. The return of firm investment is then given by $(v_t + (1-\tau_t^d)d_t)x_t N_t$ where v_t denotes the value of a firm. After the derivation of the first-order conditions, we come to this point into more detail.

[18] Note that we do not model explicitly a tax rate levied on the income from savings in government bonds but $r_{t-1}B_{t-1}$ can be interpreted as real interest payments net of taxes.

The first-order conditions for utility maximization are given by[19]

$$\lambda_t = \beta E_t \left\{ \lambda_{t+1}(1+r_t) \right\} , \tag{5.11}$$

$$\lambda_t = \beta E_t \left\{ \lambda_{t+1}\big(1 + (1-\tau_t^K)(r_{t+1}^K - \delta^K)\big) \right\} , \tag{5.12}$$

$$v_t = (1-\delta)\beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t}\big(v_{t+1} + (1-\tau_{t+1}^d)d_{t+1}\big) \right\} . \tag{5.13}$$

$$\lambda_t = C_t^{-1}\left(1+\tau_t^C\right)^{-1} \tag{5.14}$$

where λ_t denotes the Lagrange multiplier for the budget constraint.

When solving (5.13) forward,[20] we can express the value of a firm as the present value of d_t, i.e. the discounted sum of all future profits

$$v_t = E_t \left\{ \sum_{s=t+1}^{\infty} \Delta_{t,s}(1-\delta)^{s-t}(1-\tau_s^d)d_s \right\} \tag{5.15}$$

where $\Delta_{t,t+1} \equiv \beta E_t \lambda_{t+1}/\lambda_t$.

Households supply their labor force to manufacturing firms (or: intermediate goods producers) and product creators. Total hours worked are determined by the following intratemporal optimality condition:

$$(1-\tau_t^L)w_t = \chi_t L_t^{\eta} C_t (1+\tau_t^C) . \tag{5.16}$$

The optimal labor supply equation implies that both a decrease in labor and in consumption taxes leads ceteris paribus to an increase in total hours worked and consumption.

[19] Remark: In the following, we will investigate amongst others an increase in government spending financed by lump-sum or distortionary taxation. However, we assume that bonds always exist. This is analogous to assumptions in the baseline New Keynesian and RBC model where government spending is not existent but bonds exist. Consequently, households have always the possibility to invest in bonds and thus shift current consumption into the future.

[20] The forward solution of (5.13) is given by

$$\begin{aligned} v_t &= (1-\delta)E_t \left\{ \Delta_{t,t+1}(v_{t+1} + (1-\tau_{t+1}^d)d_{t+1}) \right\} \\ &= (1-\delta)E_t \left\{ \Delta_{t,t+1}([(1-\delta)\Delta_{t+1,t+2}(v_{t+2} + (1-\tau_{t+2}^d)d_{t+2})] + (1-\tau_{t+1}^d)d_{t+1}) \right\} \\ &= (1-\delta)E_t \left\{ \Delta_{t,t+1}(1-\tau_{t+1}^d)d_{t+1} \right\} + (1-\delta)^2 E_t \left\{ \Delta_{t,t+2}(v_{t+2} + (1-\tau_{t+2}^d)d_{t+2}) \right\} \\ &= (1-\delta)E_t \left\{ \Delta_{t,t+1}(1-\tau_{t+1}^d)d_{t+1} \right\} + (1-\delta)^2 E_t \left\{ \Delta_{t,t+2}(1-\tau_{t+2}^d)d_{t+2} \right\} \\ &\quad + (1-\delta)^3 E_t \left\{ \Delta_{t,t+3}(1-\tau_{t+3}^d)d_{t+3} \right\} + \ldots \\ &= E_t \left\{ \sum_{s=t+1}^{\infty} \Delta_{t,s}(1-\delta)^{s-t}(1-\tau_s^d)d_s \right\} \end{aligned}$$

where $\Delta_{t,t+1} \equiv \beta E_t \lambda_{t+1}/\lambda_t$, $\Delta_{t,t+2} = \Delta_{t,t+1} \cdot \Delta_{t+1,t+2} = \beta \frac{\lambda_{t+1}}{\lambda_t} \cdot \beta \frac{\lambda_{t+2}}{\lambda_{t+1}} = \beta^2 \frac{\lambda_{t+2}}{\lambda_t}$ and $\Delta_{t,t+3} = \Delta_{t,t+2} \cdot \Delta_{t+2,t+3}$.

5.2.5 Aggregation

Aggregating the budget constraint across households, using the equilibrium condition $x_{t+1} = x_t = 1$,[21] as well as the government budget constraint

$$G_t + (1 + r_{t-1})B_{t-1} = B_t + \tau_t^L w_t L_t + \tau_t^C C_t + \tau_t^d d_t N_t + \tau_t^K (r_t^K - \delta) K_{t-1} + \tau_t \tag{5.17}$$

yields the overall resource constraint

$$Y_t^C + v_t N_{E,t} = w_t L_t + N_t d_t + r_t^K K_{t-1}\,, \tag{5.18}$$

where $Y_t^C = C_t + I_t + G_t$ denotes aggregate demand of final goods and $v_t N_{E,t}$ is investment in new firms. G_t is government consumption which is described by the AR(1) process: $G_t = (1 - \rho_g)G + \rho_g G_{t-1} + \varepsilon_t^G$, where ε_t^G is white noise and $0 \leq \rho_g < 1$. Following Bilbiie, Ghironi, and Melitz (2007a), we define total investment as $TI_t \equiv I_t + I_{E,t}$ where $I_{E,t} \equiv N_{E,t} v_t$ denotes investment in new firms. The gross domestic product (GDP), Y_t, is equal to $Y_t \equiv Y_t^C + N_{E,t} v_t$.[22]

The complete RBC model with endogenous firm entry and capital in production is shown in Table 5.1.

5.2.6 The Benchmark Model

In order to generate a benchmark for our analysis, we apply a standard RBC model with a constant extensive margin. It can be obtained by setting $N_{E,t} = 0$ and normalizing the mass of firms to $N_t = N = 1$. This implies $L_t^E = 0$, $L_t = L_t^C$, $\rho_t = 1$,[23] $Y_t = Y_t^C$, and $TI_t = I_t$.

5.3 Parameter Estimates

In this section, we estimate the structural entry model using Bayesian techniques.[24] The estimation is based on US data for the quarterly growth rates of real GDP, real consumption, hours worked, the real wage, and net business formation over the sample period 1964Q2 to 1995Q3.[25] All series are demeaned prior to estimation.[26]

[21] In equilibrium all shares of firms are owned by the households.

[22] As in Chapter 2, we have to distinguish between total output and GDP since by assumption entry costs are *not* paid in terms of the consumption good but in terms of labor.

[23] In contrast to the entry model, the price level set by a firm now coincides with the aggregate price level since without an endogenous mass of firms the aggregate price index simplifies to

$$P_t = \left(\int_0^1 p_t(\omega)^{1-\zeta} d\omega \right)^{1/(1-\zeta)}$$

Due to the assumption of homogeneity across firms it follows that $P_t = p_t$ implying that $\rho_t = p_t / P_t = 1$.

[24] We estimate and simulate the model in non-linear form using Dynare V.4. The corresponding steady state system is numerically computed by an own Matlab file. They are shown in the Appendix.

[25] A full description of the data is given in the Appendix. The sample period is limited through the lack of data on net business formation.

[26] Since the applied model abstracts from trend inflation or GDP growth in the steady state, we have to subtract the mean of the respective growth rates from our data series.

Description	Equation
Consumption Euler	$C_t^{-\sigma}/(1+\tau_t^C) = \beta E_t \left\{ C_{t+1}^{-\sigma}/(1+\tau_{t+1}^C)(1+r_t) \right\}$
Capital Euler	$C_t^{-\sigma}/(1+\tau_t^C) = \beta E_t \left\{ C_{t+1}^{-\sigma}/(1+\tau_{t+1}^C)\big(1+(1-\tau_t^K)(r_{t+1}^K - \delta^K)\big) \right\}$
Shares Euler	$v_t = (1-\delta)\beta E_t \left\{ C_{t+1}^{-\sigma}(1+\tau_t^C)/\big(C_t^{-\sigma}(1+\tau_{t+1}^C)\big)\big(v_{t+1} + (1-\tau_{t+1}^d)d_{t+1}\big) \right\}$
Labor supply	$(1-\tau_t^L)w_t = \chi L_t^\eta C_t^\sigma (1+\tau_t^C)$
GDP	$Y_t = Y_t^C + v_t N_{E,t}$
Aggregate demand	$Y_t^C = C_t + I_t + G_t$
Investment in new firms	$I_{E,t} = v_t N_{E,t}$
Total profit income	$N_t d_t = (1-(\zeta_t - 1)/\zeta_t)\, Y_t^C$
Pricing	$\rho_t = \zeta_t/(\zeta_t - 1) mc_t$
Real wage	$w_t = \alpha(\zeta_t - 1) Y_t^C/(\zeta L_t^C)$
Rental rate	$r_t^K = (1-\alpha)(\zeta - 1) Y_t^C/(\zeta_t K_{t-1})$
Labor in manufacturing	$Y_t^C = \rho_t z_t (L_t^C)^\alpha K_{t-1}^{1-\alpha}$
Labor in entry	$L_t^E = f_{E,t}/z_t N_{E,t}$
Capital accumulation	$K_t = (1-\delta^K)K_{t-1} + I_t$
Number of firms	$N_t = (1-\delta)(N_{t-1} + N_{E,t-1})$
Free entry	$v_t = (f_{E,t}/z_t) w_t$
Real price	$\rho_t = N_t^{1/(\zeta_t - 1)}$

Table 5.1: *The complete RBC model with firm entry and capital in production*

In order to generate data-consistent time series from the model, we divide the real model variables C_t, Y_t, and w_t by the relative price ρ_t.[27] The measurement equations then read as follows:

$$\text{data\_GDP}_t = \left(\frac{Y_t/\rho_t}{Y_{t-1}/\rho_{t-1}} - 1\right) 100\,, \qquad \text{data\_WAGE}_t = \left(\frac{w_t/\rho_t}{w_{t-1}/\rho_{t-1}} - 1\right) 100\,,$$

$$\text{data\_CONS}_t = \left(\frac{C_t/\rho_t}{C_{t-1}/\rho_{t-1}} - 1\right) 100\,, \qquad \text{data\_HOURS}_t = \left(\frac{L_t}{L_{t-1}} - 1\right) 100\,,$$

$$\text{data\_NBF}_t = \left(\frac{N_t}{N_{t-1}} - 1\right) 100\,.$$

The application of five data series requires at least five exogenous disturbances. Therefore, we estimate the baseline model including shocks to government consumption, ε_t^g, to total factor productivity, ε_t^z, to entry costs, $\varepsilon_t^{f_E}$, to labor supply, ε_t^χ, and to the price mark-up, ε_t^ζ.

[27] Bilbiie, Ghironi, and Melitz (2007a) point out that for data-consistency real model variables should be deflated by p_t instead of P_t.

The following parameters are kept fixed in the estimation procedure. The discount rate, β, is fixed equal to 0.99 implying an annual steady state real interest rate of approximately 4 percent. The quarterly capital depreciation rate, δ^K, is set to the standard value 0.025. The share of labor in the production function, α, is set to 0.8 which is the value estimated by Smets and Wouters (2007). Following Bilbiie, Ghironi, and Melitz (2007a, 2007b) and Lewis (2009b), the value of the elasticity of substitution between intermediate goods, ζ, is set to 3.8.[28] For reflecting the US economy, the steady state tax rates and steady state government consumption are set to $\tau^C = 0.05$, $\tau^L = 0.28$, $\tau^K = 0.36$, and $G/Y = 0.18$ which are values calculated by Trabandt and Uhlig (2009). The steady state tax rate on dividend income, τ^d, is equalized to the steady state tax rate on capital income. Throughout the estimation process, χ is computed endogenously such that in the steady state 1/3 of time is devoted to work. The steady state value of total factor productivity, z, is normalized to 1.

For the remaining parameters we choose priors for the Bayesian estimation following previous literature, in particular Smets and Wouters (2007). Table 5.2 shows the prior distribution, alongside with the estimated parameters as modes of the posterior distribution and the 95 percent confidence intervals obtained by the Metropolis-Hastings algorithm [see Metropolis et al. (1953) and Hastings (1970) or Chib and Greenberg (1995)]. The standard deviations of shocks are assumed to be inverse-gamma distributed with a mean of 0.01. The prior means for the autoregressive parameters are beta distributed with prior means of 0.5 and standard deviations of 0.2. We assume a normal distribution for the inverse of the Frisch elasticity of labor supply, η. The prior mean of 1 and the standard deviation is chosen to cover a wide range of parameter values typical used in calibration exercises. The entry cost, f_E, is assumed to be normal distributed with a prior mean of 1 and a standard deviation of 0.5.[29] Finally, the firm exit rate, δ, is beta distributed with a mean of 0.025 which is the calibrated value used by Bilbiie, Ghironi, and Melitz (2007a) to match the average annualized job destruction rate in the US.

The results of the Bayesian estimation are shown in Table 5.2. It depicts that the processes for government spending, total factor productivity, entry costs, and for the labor supply shock are highly persistent with an AR(1) coefficient of 0.92, 0.99, 0.98, and 0.98, respectively.[30] The persistence of the price mark-up shock is quite

[28] Although this value seems to be rather small, Lewis and Poilly (2010) estimate the elasticity of substitution between intermediate goods to be even smaller (3.31) in a model with firm entry.

[29] Remark: Bilbiie, Ghironi, and Melitz (2007a) log-linearize their model and conclude that the steady state of the entry costs cancels out and thus does not affect the resulting dynamics, at all. By contrast, we apply the non-linear representation. Hence, the steady state of the entry costs now plays a crucial role by determining the steady state value of v_t and thus influences the dynamics of the whole entry mechanism.

[30] The mode and the mean are both consistent estimators. In our estimation they are moreover very close to each other. We take the modes to calibrate our model since the inverse of the Frisch elasticity is slightly lower and the persistence of the fiscal demand shock is slightly higher. The impact of these parameters will be investigated in Section 5.4.

Parameters		Prior distribution			Posterior distribution		
		Type	Mean	Std. Dev.	Mode	Mean	Confid. Interval
Inv. of Frisch elasticity	η	Normal	1	0.75	2.9899	3.1761	[2.3784 – 4.0188]
Firm exit rate	δ	Beta	0.025	0.01	0.0966	0.0944	[0.0810 – 0.1073]
Entry cost	f_E	Normal	1	0.5	0.3398	0.3535	[0.2866 – 0.4165]
Persistence of g shock	ρ_g	Beta	0.5	0.2	0.9287	0.8879	[0.8125 – 0.9714]
Persistence of z shock	ρ_z	Beta	0.5	0.2	0.9990	0.9984	[0.9970 – 0.9998]
Persistence of f_E shock	ρ_{f_E}	Beta	0.5	0.2	0.9758	0.9604	[0.9319 – 0.9908]
Persistence of ζ shock	ρ_ζ	Beta	0.5	0.2	0.1943	0.1948	[0.1190 – 0.2733]
Persistence of χ shock	ρ_χ	Beta	0.5	0.2	0.9838	0.9819	[0.9694 – 0.9948]
Std. dev. g shock	ε_t^g	Inv. Gam.	0.01	2	0.0536	0.0709	[0.0384 – 0.0997]
Std. dev. z shock	ε_t^z	Inv. Gam.	0.01	2	0.0148	0.0154	[0.0132 – 0.0176]
Std. dev. f_E shock	$\varepsilon_t^{f_E}$	Inv. Gam.	0.01	2	0.0177	0.0164	[0.0128 – 0.0197]
Std. dev. ζ shock	ε_t^ζ	Inv. Gam.	0.01	2	0.0852	0.0876	[0.0757 – 0.0992]
Std. dev. χ shock	ε_t^χ	Inv. Gam.	0.01	2	0.0258	0.0274	[0.0211 – 0.0334]

Table 5.2: *Results from the Bayesian estimation including prior distribution and confidence intervals*

low. These results are consistent with studies such as Smets and Wouters (2007). The point estimate of the inverse of the Frisch elasticity of labor supply, η, is approximately 3 with a 95 percent confidence interval from 2.4 to 4. The confidence interval for the entry cost ranges from 0.29 to 0.42 with a point estimate of around 1/3. Finally, our estimation delivers a firm exit rate of about 10 percent. This high value is more in line with the findings of Broda and Weinstein (2010) who report a product turnover rate of about of 6.25 percent than with the calibrated 2.5 percent used by Bilbiie, Ghironi, and Melitz (2007a). Notice that – as pointed out in Lewis and Poilly (2010) and Bilbiie, Ghironi, and Melitz (2007a) – a higher value of δ implies less persistent dynamics. Remarkably, the data seems to speak in favor of a high value (less persistent dynamics) although we are estimating a rather simple model without features that generates additional persistence such as habit persistence or capital adjustment costs. This finding suggests that the entry mechanism per se leads to sufficiently persistent dynamics.

5.4 Estimated Responses to a Government Consumption Shock

In this section, we analyze the effects of an increase in government consumption, G_t, financed by raising lump-sum taxes.[31] We use the estimated model to analyze the impulse responses and to discuss the ambiguous reaction of investment in new firms and consequently of the mass of firms.

Figure 5.2 displays the estimated impulse responses to an increase in government

[31] Due to Ricardian equivalence it does not matter whether an increase in government spending is financed by lump-sum taxes or by issuing bonds since both interventions lead to the same wealth effect [cf. Buchanan (1976)].

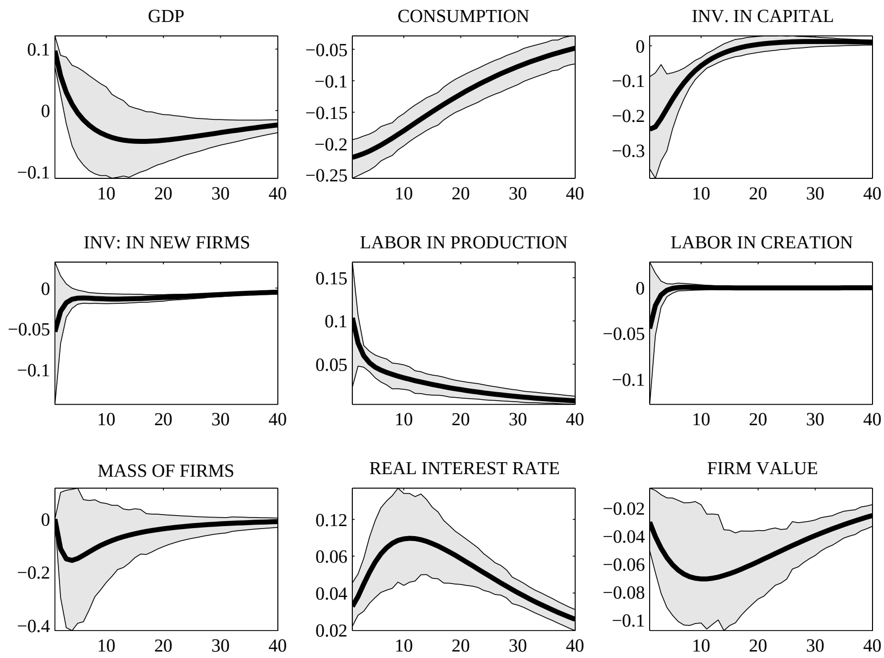

Figure 5.2: *Impulse responses to a temporary increase in government consumption*

consumption.[32] The solid lines are the means of the distribution of impulse response functions, the grey shaded areas depict the 90 percent highest probability density intervals. Figure 5.2 shows that in response to an increase in government consumption, private consumption, and investment in physical capital decline significantly. The reason is the negative wealth effect of a rising tax burden [see Baxter and King (1993)]. The wealth effect also causes households to expand their total labor supply which in turn induces a decline in real wages and a significant expansion of output.

The insignificant reactions of hours worked in the new product sector, of investment in new firms, and of the total mass of firms suggest that the reaction of the extensive margin in response to a government spending shock is ambiguous.[33] This was already mentioned by Lewis (2009b) within a calibrated firm entry model with sticky prices and labor as the only input factor. Lewis (2009b) points out that the mass of producers only increases for sufficiently high degrees of fiscal shock persistence, ρ_g. The rationale is that only under highly persistent shocks, the expected future profits will cover the entry costs such that new firm creation is boosted. This result

[32] The number of years are on the abscissa. However, we interpret periods as quarters. On the ordinate we plot the percentage deviation of a variable from the corresponding steady state value, i.e. $x_t = (X_t - \overline{X})/\overline{X}$, where $\overline{X}$ is the steady state value. Further note that all variables under consideration return to their initial steady state.

[33] Remark: In the longer-run the contractionary reactions of investment in new firms and of the mass of firms become significant.

also holds in our estimated RBC model considering capital in production.

Notably, we find that the response of the mass of firms does not only depend on the shock persistence in insolation but on the combination of the latter with the labor supply elasticity, $1/\eta$. In the following exercise, we focus on investment in new firms which will be important for the analysis of the effectiveness of fiscal policy because it affects GDP via two channels. The following equation for GDP, Y_t, reveals these two channels:

$$Y_t \equiv v_t N_{E,t} + \underbrace{N_t^{\frac{\zeta}{\zeta-1}} y_t}_{Y_t^C} \tag{5.19}$$

First, investment in new firms, $v_t N_{E,t}$, is naturally a component of GDP. Second, investment in new firms changes the mass of firms, N_t, which in turn has an impact on the overall production of final goods. Analytically, the latter effect follows from the aggregation of intermediate goods since an increase in the mass of products has ceteris paribus a positive effect on aggregate production since $\zeta > 1$. This effect is known as 'love of variety' [see Benassy (1996) or Bergin and Corsetti (2008)]. This effect directly follows from the aggregation of intermediate goods ($Y_t^C = N_t^{\zeta_t/(\zeta_t-1)} y_t$) and implies that an increase in the mass of firms has ceteris paribus a positive impact on aggregate production. Note that a decrease in investment in new firms represents an additional crowding-out effect of fiscal policy that is absent in a model with a constant extensive margin.

In order to analyze how firm entry depends on ρ_g and η, we simulate the model under a range of parameter values for $\rho_g = [0, 1)$ and $\eta = [1, 4]$ keeping the remaining parameters fixed to the estimated modes shown in Table 5.2.

Figure 5.3 shows investment in new firms (grey area) and the zero plane (white shaded area) from two different lines of sight. Figure 5.3 indicates that the development of this type of investment and thus of the extensive margin is unambiguously expansionary for a high degree of shock persistence. Moreover, the model also generates an expansionary reaction of this type of investment for lower degrees of shock persistence if the Frisch elasticity of labor supply, $1/\eta$, is sufficiently large, i.e. η is sufficiently small. By contrast, the reaction turns negative if the shock persistence is low and the labor supply is sufficiently inelastic.

The economic intuition why the reaction of the mass of firms may turn negative when the labor supply elasticity is low is straightforward. Therefore, let us conduct the following thought experiment and consider the limiting case of a totally inelastic labor supply. Let us moreover abstract from capital such that labor is the only input factor in production. Accounting for these assumptions within an RBC model with a fixed mass of producers, employment and thus output will remain unchanged after an increase in government spending. Government consumption consequently

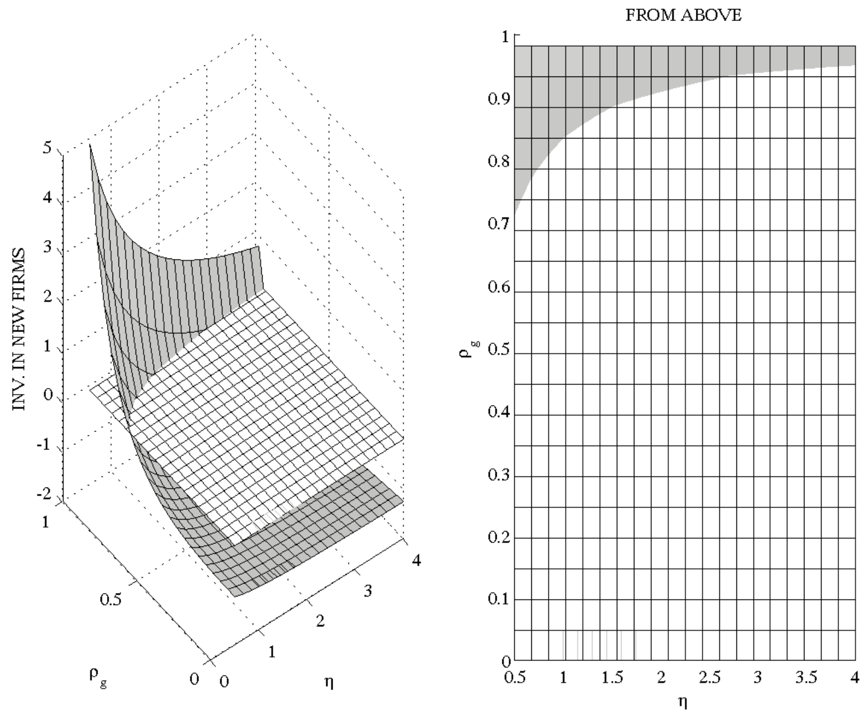

Figure 5.3: *On the ambiguous reaction of investment in new firms [white area: zero plane, grey area: investment in new firms]*

causes a complete crowding-out of private consumption. In the entry model, however, households can reallocate their labor force between working in the manufacturing sector and creating new products. Households are then able to dampen the drop in private consumption without reducing leisure just by increasing hours worked in the manufacturing sector in the same amount as they decrease hours devoted to product creation. Product variety consequently declines when the inverse of the labor supply elasticity, η, is large.

All in all, Figure 5.3 depicts that the qualitative reaction of investment in new firms and thus of the extensive margin is ambiguous. By contrast, Bilbiie, Ghironi, and Melitz (2007a) and Bergin and Corsetti (2008) respectively show that technological innovations and shocks to monetary policy are unambiguously amplified by endogenizing the extensive margin. In line with these findings, it is worth mentioning that the estimated response of the mass of firms to the other shocks under consideration are unambiguous. Figure 5.4 shows that in response to an increase in total factor productivity, firm entry is boosted significantly. By contrast, a cost-push shock, a utility shock, and an increase in entry costs lead to a significant fall in the mass of firms.

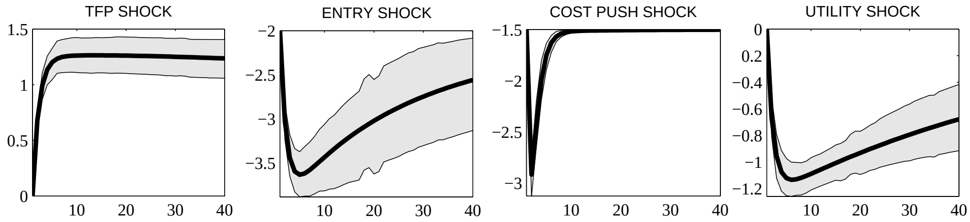

Figure 5.4: *Impulse responses of the mass of firms to different shocks*

5.5 Multiplier Analysis

After having analyzed the impulse responses to an increase in government consumption, we now investigate the return of a fiscal stimulus, the fiscal multiplier. Thereby, we do not focus only on a pure demand stimulus, but also consider other fiscal stimuli in form of income or consumption tax cuts. For the purpose of comparability, we normalize the corresponding innovations such that the cost of each fiscal package amounts to 1% of GDP in the implementation period.

For each fiscal intervention, we compute a dynamic multiplier as proposed by Uhlig (2010). The value of this multiplier at time t is equal to the sum of discounted GDP changes until time t divided by the sum of discounted cost changes until time t

$$\text{dynamic multiplier}_t = \frac{\sum_{s=0}^{t} \beta^s \Delta Y_s}{\sum_{s=0}^{t} \beta^s \Delta G_s}. \tag{5.20}$$

By setting $t = 4$ and $t \to \infty$, we obtain the short-run and the long-run multiplier, respectively. The short-run multiplier is thus defined as the discounted change in GDP in the first year divided by the discounted costs of a fiscal stimulus during the first year. The long-run multiplier is defined as the discounted overall output effects divided by the discounted overall costs.

To highlight the role of firm entry, we compare the results in our baseline entry model with those in the standard RBC model sketched in Section 5.2.6.

5.5.1 The Pure Demand Stimulus

The evaluation of the pure demand stimulus yields a short-run and a long-run multiplier amounting to 0.09 and -0.30, respectively. Thereby, the reaction of the mass of firms becomes a decisive factor when comparing the fiscal multipliers with those obtained by a standard RBC framework. In comparison with the standard RBC model, the short-run multiplier remains approximately unchanged while the long-run multiplier is about 36% smaller.[34] The reason is that investment in new firms

[34] Remark: Consequently, the long-run multiplier is also negative in the standard RBC model when applying our estimated parameters.

and consequently the mass of firms decline as shown in Figure 5.4. This additional crowding-out effect pushes down the effectiveness of an increase in government consumption.

Figure 5.5 shows that the fiscal multiplier generated by the entry model exceeds that under a constant extensive margin only if the mass of firms increases. Figure 5.5 is based on simulations of the model for different values of the Frisch elasticity of labor supply and the shock persistence, keeping the remaining calibration unchanged. More precisely, the figure shows dynamic fiscal multipliers for both the entry model and the standard RBC model with a constant mass of firms for the boundaries of the estimated confidence intervals of $\rho_g = \{0.81, 0.97\}$ and $\eta = \{2.38, 4.02\}$. The left panel shows the fiscal multiplier for the case of a high shock persistence and a relatively elastic labor supply ($\rho_g = 0.97$, $\eta = 2.38$). This parameter set leads to an increase in the mass of firms which in turn pushes the dynamic multiplier above that of the RBC model with a constant extensive margin. The right panel is based on the opposite case of a low shock persistence and a more inelastic supply of labor ($\rho_g = 0.81$, $\eta = 4.02$) which leads to decrease in the mass of firms and thus yields a smaller multiplier compared to the standard RBC model.

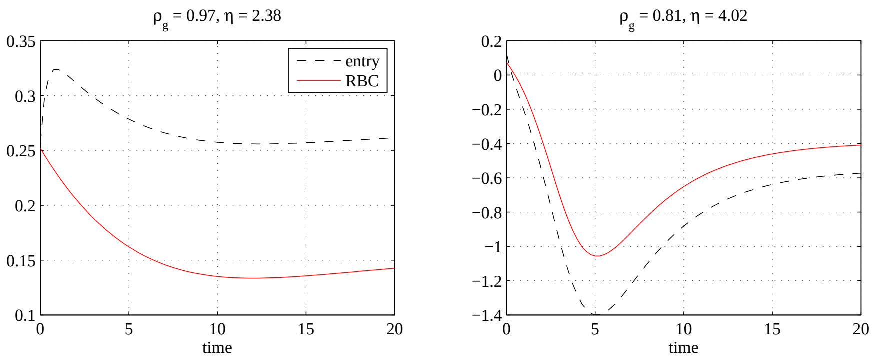

Figure 5.5: *Fiscal multipliers for the endogenous entry and a standard RBC model*

As a general rule, the mass of firms acts as an accelerator for the positive impacts of fiscal stimuli if the mass of firms increase while it acts as a decelerator if the mass of firms decreases.[35] As will be shown later, this result also holds in the case of other fiscal interventions such as tax cuts or demand stimuli under distortionary taxation.

5.5.2 Tax Cuts

After having analyzed the impacts of an increase in government consumption, we now turn to other forms of fiscal stimuli, namely tax cuts. In what follows, we stick to the assumption that an increase in government spending (now in form of

[35] A more detailed graphical analysis of the fiscal multiplier and the mass of firms for different parameter sets of ρ_g and η can be found in Appendix.

consumption and income tax cuts) is financed via lump-sum taxation. We consider temporary cuts in consumption, labor, capital income, and dividend income taxes, all of the following form

$$\tau_t^i = (1-\rho_i)\tau^i + \rho_{\tau^i}\tau_{t-1}^i - \varepsilon_t^{\tau^i} \quad \text{for} \;\; i = C, L, K, d\,, \tag{5.21}$$

where the persistence of the AR(1) processes describing the evolution of the tax cuts are set to $\rho_{\tau^i} = \rho_g$ for $i = C, L, K, d$.

The aim of this exercise is twofold. First, we want to compare the effectiveness of different forms of fiscal stimuli. Second, we want to check the robustness of our finding that firm entry can accelerate and decelerate the multiplier effects.

The labor tax cut

Figure 5.6 shows the impulse responses to a labor tax cut for the firm entry model and the standard RBC model as well as the resulting dynamic multipliers. The cut in labor taxes induces households to increase both time spent to create new products and to work for intermediate good producers causing a decline in the real wage and an increase in output. In contrast to the increase in government consumption, private consumption now reacts expansionary since the net wealth effect is positive.

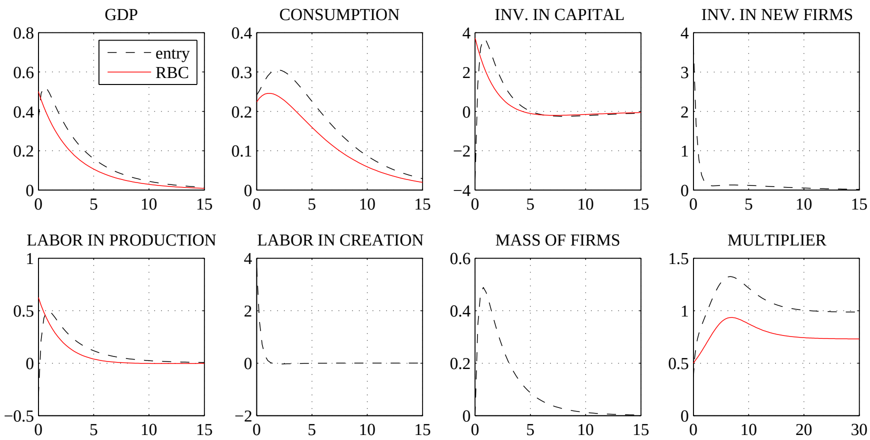

Figure 5.6: *Impulse responses to a temporary cut in labor taxes*

Higher goods demand and lower marginal costs result in higher profit opportunities for firms in the intermediate goods market. As new product creation becomes temporarily more profitable, investment in new firms increases. This effect is in turn amplified by decreasing entry costs. By contrast, investment in existing capital decreases on impact. Thereafter, the reaction turns positive. All in all, total investment (not depicted here) reacts expansionary. In the RBC model investment in physical capital increases due to the positive wealth effect. The rise in the mass of firms results in a fiscal multiplier above that of the RBC model by about 8% in the short-run and 36% in the long-run.

The capital income tax cut

Figure 5.7 depicts the impulse responses to a capital tax cut and the resulting multipliers. In both models, the capital tax cut triggers a boom in capital investment. Since households know the tax cut to be temporary, they use their resources to finance the increase in physical capital. Households consequently lower consumption and increase their labor supply. In the entry model, households additionally shift labor time from product creation to the manufacturing sector in order to take advantage of the subsidized input factor which is not used for product creation in the applied framework. As a consequence, investment in new firms drops. In the entry model there thus exists a substitution relation between the two types of investment. The decline in new product investment causes a decrease in the mass of products.

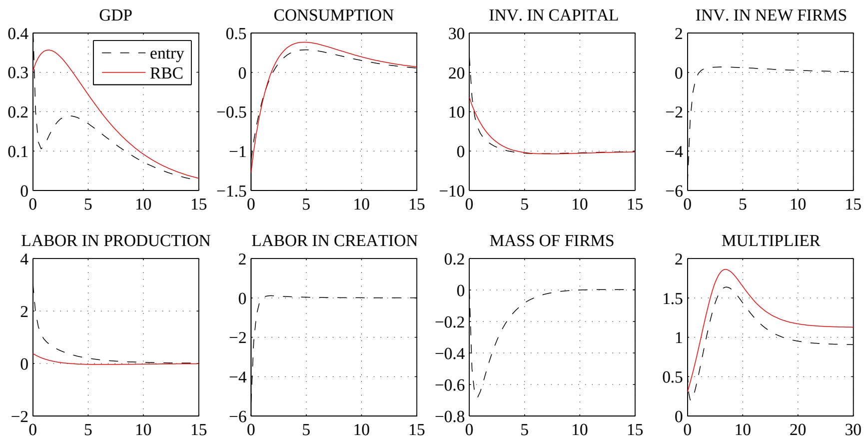

Figure 5.7: *Impulse responses to a temporary cut in capital income taxes*

The substitution relation between new firm investment and capital investment can analytically be shown by substituting (5.12) in (5.13):

$$v_t = \frac{(1-\delta)(v_{t+1} + (1-\tau^d_{t+1})d_{t+1})}{1 + (1-\tau^K_t)(r^K_{t+1} - \delta^K)}. \tag{5.22}$$

From (5.22) it directly follows that a drop in capital income tax, τ^K_t, causes the real value of an operating firm in the intermediate goods sector, v_t, to decrease. This in turn induces a contractionary reaction of investment in new firms.

When compared to the RBC model, the firm entry model generates significantly smaller multipliers – 22% smaller in the short-run and 20% smaller in the long-run

– caused by the additional crowding-out of new firm investment.

The dividend income tax cut

Figure 5.8 shows the impulse responses to a dividend income tax cut, τ_t^d. In the standard RBC model, profits only represents a residual. Consequently, the dividend income tax cut is lump-sum in the framework without an endogenous mass of firms. Hence, it does not affect the dynamics of the economy, at all. In the entry model, however, the cut in dividend taxes increases after tax profits which induces households to invest in new firms. Therefore, private agents shift labor from the manufacturing sector towards the creation of new products. To finance the boom in product creation, capital investment is sharply reduced on impact. Again, the model depicts the substitution relation between the two types of investment. As in the case of the capital tax cut, the non-subsidized investment form drops for the sake of increasing the other one. Since the increase in investment in new firms exceeds the decline in that in physical capital, total investment reacts expansionary.

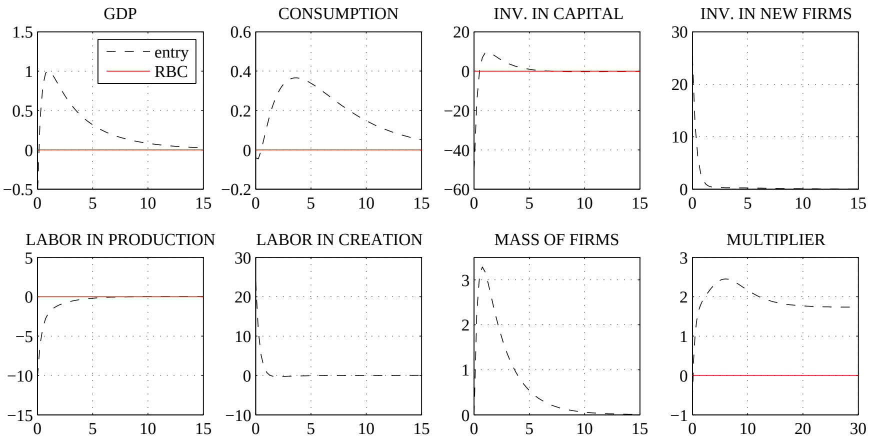

Figure 5.8: *Impulse responses to a temporary cut in dividend income taxes*

Analytically, the substitution relation can be shown by re-arranging (5.22):

$$r_{t+1}^K = \frac{(1-\delta)(v_{t+1} + (1-\tau_{t+1}^d)d_{t+1}) - v_t}{(1-\tau_t^K)v_t} + \delta^K. \tag{5.23}$$

It follows that a dividend tax cut increases, in isolation, the rental rate of physical capital which equals the marginal product of capital. An increase in the marginal product of capital requires a decrease in physical capital and thus a drop in capital investment.

Figure 5.8 depicts that consumption increases due to the positive wealth effect resulting from higher labor income. Since labor used for product creation rises more than hours worked in the manufacturing sector decreases, total hours worked also react expansionary. All in all, the dividend tax cut has an expansionary effect on GDP since it induces a crowding-in of private consumption, total investment, and product variety which in turn leads to a larger multiplier when compared to a cut in capital taxes.

The simultaneous cut in the capital and dividend income tax

Up to now, we have assumed that capital income and dividend income are taxed separately. Since there exists a trade-off between investment in physical capital and investment in new firms, an isolated cut in capital income taxes leads, on the one hand, to an increase in capital investment but comes at the cost of a decline in investment in new products. A cut in dividend income taxes, on the other hand, triggers a boom in investment in new firms and a decline in capital investment. In reality, governments however do not distinguish between the income from renting capital to firms and the profit income from holding shares of these firms. Therefore, we now assume that there exists a unified tax rate on capital and dividend income, i.e. $\tau_t^d = \tau_t^K$.[36]

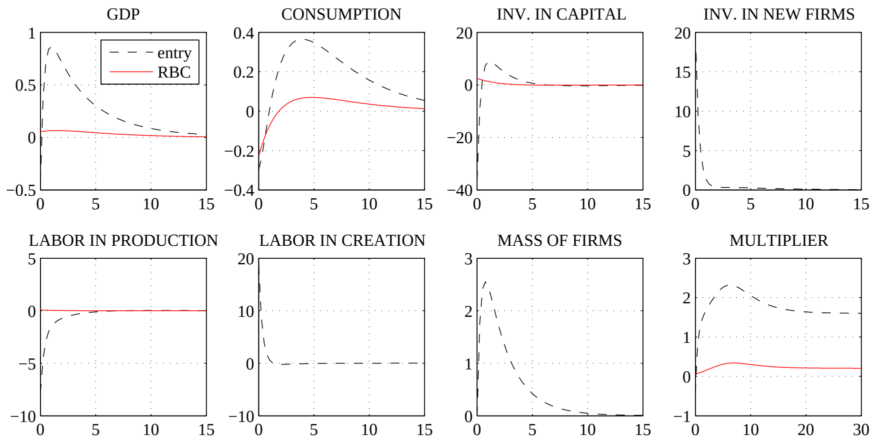

Figure 5.9: *Impulse responses to a simultaneous temporary cut in capital and dividend income taxes*

Figure 5.9 shows impulse responses to a cut in the unified tax rate on dividend and capital income. In the entry model, the impacts of a combined dividend and capital tax cut turn out to be qualitatively equivalent to those of an isolated cut in dividend taxes. The results show a sharp initial decline in capital investment but a jump in investment in new firms which in turn leads to an increase in the mass of firms. This increase amplifies the fiscal multiplier significantly by about seven times, when

[36] Note that this fiscal package is still normalized such that the cost of the fiscal stimulus in the implementation period amounts to 1% of GDP.

compared to the RBC model with a fixed mass of firms.

The rationale is that in the RBC model, this fiscal package has much smaller positive effects since part of the package is 'wasted' for a cut in dividend taxes which is completely lump-sum and thus ineffective in stimulating economy activity if the mass of firms is constant.

The consumption tax cut

The last fiscal stimulus under consideration is a cut in consumption taxes. Figure 5.10 shows the corresponding impulse responses. The temporary tax cut stimulates aggregate demand through an increase in private consumption. Otherwise, the results for a cut in consumption taxes are qualitatively equivalent to those in response to an increase in government consumption described above. This is a plausible result since both fiscal interventions are expansionary shocks to goods demand. In contrast to the standard RBC model with a constant mass of producers, the consumption tax cut crowds out investment in new firms.[37] As a result, the extensive margin decreases. This in turn dampens the long-run multiplier effects compared to the RBC model by about 33%. As in the case of a pure demand stimulus, the short-run multiplier remains however unaffected.

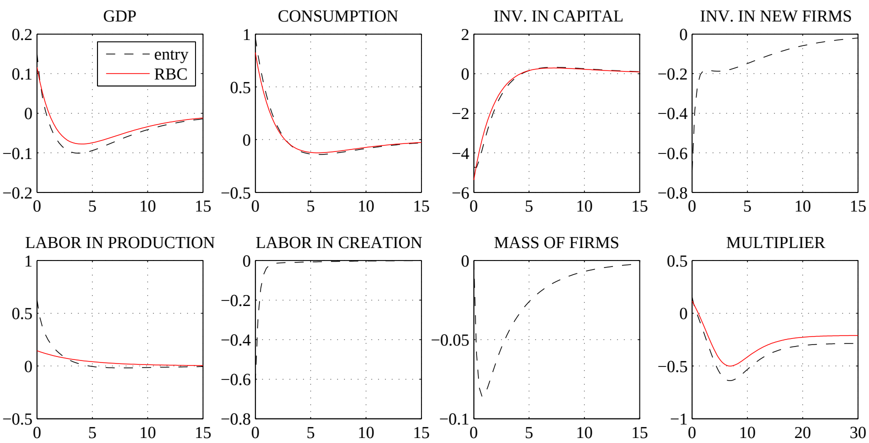

Figure 5.10: *Impulse responses to a temporary cut in consumption taxes*

Robustness checks

In Section 5.4, we have demonstrated that the sign of the response of the mass of firms to an increase in government consumption is ambiguous when varying the labor supply elasticity, η, and the shock persistence, ρ_g. In line with these findings, Table 5.3 shows that we obtain the same result for a consumption tax cut. This

[37] In the next section (*Robustness checks*), we will show that as in the case of an increase in government consumption, the reaction of the mass of firms is also ambiguous in response to a consumption tax cut.

is not surprising since we already pointed out that the qualitative results for a cut in consumption taxes are equivalent to those for an increase in government consumption.

Stimulus τ_i	$\eta = 4.02$	$\eta = 3.17$	$\eta = 1$	$\rho_{\tau_i} = 0$	$\rho_{\tau_i} = 0.89$	$\rho_{\tau_i} = 0.97$
τ^C	$-$	$-$	$+$	$-$	$-$	$+$
τ^L	$+$	$+$	$+$	$+$	$+$	$+$
τ^K	$-$	$-$	$-$	$-$	$-$	$-$
τ^d	$+$	$+$	$+$	$+$	$+$	$+$
$\tau^K = \tau^d$	$+$	$+$	$+$	$-$*	$+$	$+$

* $\rho \geq 0.08$ is however sufficient to obtain an increasing mass of firms.

Table 5.3: *Response of the mass of firms [+ : expansionary reaction of the mass of firms, − : contractionary reaction of the mass of firms]*

However, when regarding isolated labor, capital, and dividend income tax cuts, results change. Under these fiscal stimuli, the sign of the reaction of the mass of firms is unambiguous. The extensive margin always reacts expansionary in the case of a cut in labor and dividend income taxes, whereas it always decreases when considering a cut in capital taxation. Only if capital and dividend income taxes are not distinguishable, some degree of autocorrelation is necessary to ensure that the positive impact of the dividend tax cut dominates the contractionary impact of the cut in capital income taxes. Under our baseline calibration a degree of autocorrelation amounting to $\rho_g \geq 0.08$ is sufficient to obtain an increasing mass of firms.

5.5.3 The Different Stimuli at a Glance

Table 5.4 shows the short- and long-run fiscal multipliers for the previously analyzed fiscal stimuli in both models and indicates the qualitative reaction of the mass of firms, N.

Stimulus	Short-Run Multiplier	% dev. of RBC	Long-Run Multiplier	% dev. of RBC	N
G	0.09	0%	- 0.30	- 36%	$-$
τ^L	0.56	8%	0.99	36%	$+$
τ^C	0.09	0%	- 0.28	- 33%	$-$
τ^K	0.32	- 22%	0.90	- 20%	$-$
τ^d	0.45	n.a.*	1.73	n.a.*	$+$
$\tau^K = \tau^d$	0.44	529%	1.60	700%	$+$

*The dividend tax cut is lump-sum in the RBC model and thus does not yield to any fluctuations, at all.

Table 5.4: *Fiscal multipliers and mass of firms, N [+ : expansionary reaction of the mass of firms, − : contractionary reaction of the mass of firms]*

The pure demand stimulus generates small short- and long-run multipliers, since the increase in government consumption causes a crowding-out of private consumption, investment in physical capital, and investment in new firms. As in the RBC model, the long-run multiplier becomes even negative, -0.30. As already mentioned, the cut in consumption tax yields qualitatively the same results as the increase in government consumption. Table 5.4 moreover shows that both interventions also perform approximately equivalent from a quantitative point of view. The decline in the extensive margin leads to a long-run multiplier which is 33% lower than in the RBC model.

In both the RBC and the firm entry model, the cuts in labor and capital taxes perform quite well. However, the cut in capital tax, in particular, generates a long-run multiplier slightly larger than one in the RBC model. By contrast, this is not the case in the entry model where the labor tax cut has a stronger impact than the capital tax cut. Since the capital tax cut comes at the cost of a crowding-out of investment in new firms, the multiplier is significantly dampened when compared to the RBC model. However, the capital tax cut still results in a positive long-run multiplier close to one. The labor tax cut results in a crowding-in of private consumption, investment in physical capital and in new firms. As a result, the multiplier becomes significantly amplified.

As already mentioned, the dividend income tax rate is lump-sum in the RBC model and thus does not result in any fluctuations, at all. In the entry model, however, this tax cut has strong effects (1.73) since it causes all components of GDP to increase over the cycle. This policy intervention is thus more effective than for instance the cut in capital taxes. The unified cut in capital and dividend income taxes also leads to large multipliers in the endogenous entry model (1.60). However, when the mass of firms is fixed, the multiplier is very small but positive. The rationale is the lump-sum nature of dividend taxes under these circumstances and the resulting non-effectiveness of a part of the fiscal package.

Table 5.4 moreover depicts our general result since in all cases where product variety increases, the multipliers generated by the entry model exceed those of the standard RBC model. Additionally, our results imply that in line with the findings of Campolmi, Faia, and Winkler (2010) and Faia, Lechthaler, and Merkl (2010b), a pure demand stimulus leads to rather small real effects.[38] Disburdening private agents from labor, dividend, or capital income taxes is much more effective. The dividend tax cut is thereby the most effective fiscal tool since it induces a crowding-in of consumption, investment, and the extensive margin.

5.6 Distortionary Taxation

Up to now, we have assumed that fiscal interventions are financed by raising lump-sum taxes. In the following, we investigate the effects of distortionary taxation for

[38]The absolute size of the multiplier could naturally be increased by assuming for instance rule-of-thumb consumers [cf. Galí, López-Salido, and Vallès (2007)] or backward indexation of prices [cf. Chari, Kehoe, and McGrattan (2009)]. However, we and the cited authors want to analyze the *pure* effects of firm entry and frictional labor markets on fiscal multipliers, respectively.

government spending multipliers and the mass of firms. We follow Uhlig (2010) and assume that an increase in government consumption is financed partly by raising distortionary taxes on labor income and partly by issuing debt.[39] The adjustment of distortionary taxes can be analyzed by introducing the following tax rule

$$\tau_t^L w_t L_t = \phi_g\big(G_t + (1+r_{t-1})B_{t-1} - \tau_t^C C_t - \tau_t^d d_t N_t - \tau_t^K (r_t^K - \delta)K_{t-1} - \tau_t\big)\,, \tag{5.24}$$

where ϕ_g denotes the share of distortionary taxation. $\phi_g = 0$ is consequently equivalent to pure lump-sum taxation. We assume that all taxes, other than the labor income tax, stick to their steady state values, i.e., $\tau_t = \tau$, $\tau_t^C = \tau^C$, $\tau_t^K = \tau^K$, $\tau_t^d = \tau^d$.

In contrast to Uhlig (2010), we furthermore want to explore the effects of an increase in government consumption financed by raising the tax on consumption purchases as well as the unified tax on capital and dividend income. We therefore introduce the following variants of the tax rule described above:

$$\tau_t^C C_t = \phi_g\big(G_t + (1+r_{t-1})B_{t-1} - \tau_t^L w_t L_t - \tau_t^d d_t N_t - \tau_t^K (r_t^K - \delta)K_{t-1} - \tau_t\big)\,, \tag{5.25}$$

where $\tau_t^L = \tau^L$, $\tau_t = \tau$, $\tau_t^K = \tau^K$, $\tau_t^d = \tau^d$, and

$$\begin{aligned}&\tau_t^d (d_t N_t + (r_t^K - \delta)K_{t-1})\\ &\quad = \phi_g\big(G_t + (1+r_{t-1})B_{t-1} - \tau_t^C C_t - \tau_t^L w_t L_t - \tau_t^K (r_t^K - \delta)K_{t-1} - \tau_t\big)\,,\end{aligned} \tag{5.26}$$

where $\tau_t^C = \tau^C$, $\tau_t^L = \tau^L$, $\tau_t = \tau$, $\tau_t^K = \tau_t^d$.

We set $\phi_g = 0.5$ implying that half of the increase in government consumption is financed by distortionary taxation. Table 5.5 shows the resulting short- and long-run multipliers and indicates the qualitative reaction of the extensive margin. The results for $\phi_g = 0$ are obviously those shown in Table 5.4.

Stimulus	Short-Run Multiplier	% dev. of RBC	Long-Run Multiplier	% dev. of RBC	N
τ^L	- 0.35	- 6%	- 1.67	- 45%	–
τ^C	- 0.05	- 67%	- 0.06	- 20%	–
$\tau^K = \tau^d$	- 0.53	- 430%	- 6.43	- 1210%	–

Table 5.5: *Government spending multipliers and mass of firms, N, under distortionary taxation ($\phi_g = 0.5$)*

Three results are worth mentioning. First, as in Uhlig (2010), distortionary taxation of labor income leads to a strong negative long-run multiplier. This result also holds when considering distortionary taxes on the unified tax on capital and dividend income. If the increase in government consumption is however financed

[39] Remark: Then, Ricardian equivalence naturally does not hold anymore.

through an increase in consumption taxes, the short- and long-run fiscal multipliers are approximately zero in both models.[40]

Second, the quantitative response of the extensive margin does not only depend on the fiscal shock persistence and on the labor supply elasticity but also on the way an increase in government consumption is financed. Table 5.5 shows that in all cases of financing, the fiscal intervention leads to a decline in the mass of firms.

Finally, when comparing the multipliers of the entry model with those of the RBC model with a fixed mass of firms, we again find strong evidence for an additional crowding-out effect of the extensive margin. In all cases, the mass of firms reacts contractionary leading to smaller multipliers. Consequently, when assuming an endogenous mass of firms and fiscal policy financed with distortionary taxation, the short- and long-run multipliers become significantly smaller, i.e. more negative.

We obtain the strongest decelerating effects in the case of the unified tax to capital and dividend income since dividend taxation is lump-sum in the RBC model such that part of the fiscal package is ineffective. Moreover, Table 5.4 reports that the unified change in this tax rate has in isolation stronger effects than the pure fiscal demand stimulus.

5.7 Conclusion

Since recent theoretical contributions only analyze the impacts of fiscal stimuli only on standard economic measures of economic activity (GDP, employment, investment) but neglect their impact on the extensive margin, this chapter analyzes different fiscal stimuli in an estimated model with endogenous product creation.

We demonstrate that the extensive margin is a crucial dimension for evaluating fiscal policy since it can accelerate and decelerate the impacts of fiscal stimuli. More precisely, we find that if in response to a fiscal stimulus the mass of firms increases, fiscal multipliers are amplified. If, however, the mass of firms declines, the reaction of the extensive margin dampens the impact on economic activity. This result remains robust to different fiscal interventions such as tax cuts and fiscal packages financed by distortionary taxation.

We show that a pure demand stimulus and a consumption tax cut lead to small multipliers since these interventions result in an additional crowding-out effect of investment in new firms. By contrast, the multipliers of labor and dividend taxes are significantly larger since these fiscal interventions both induce a crowding-in of consumption, of investment in existing capital, and of investment in new product creation. The latter effect in turn leads to a further amplification via an increase in the mass of products.

[40] This result becomes even stronger in the case $\phi_g = 1$. Then, fiscal policy has no effects, at all.

Considering the case that the increase in government consumption is financed by distortionary income taxation, we find that the tax hike causes fiscal multipliers to become strongly negative which is even amplified by a decreasing mass of firms. This result is similar to the findings of Uhlig (2010) in the case of distortionary labor taxation. If the demand stimulus is financed with higher consumption taxes, the fiscal multiplier is approximately zero.

To highlight the role of an endogenous mass of firms for the impacts of different fiscal packages on real economic activity, we employ a Real Business Cycle model with firm entry. Thus, our framework does not allow for any role of monetary policy which, however, plays an important role as a policy response to economic downturns. The interplay of monetary and fiscal policy in a model with firm entry may thus be a promising area for future research. Moreover, the simplicity of our model precludes a thorough quantitative examination of the impacts of the ARRA fiscal stimulus packages. Future research should be to conduct a Bayesian estimation of a DSGE model with several nominal and real frictions as well as endogenous firm entry to quantify the fiscal accelerator discussed in the chapter at hand.

Appendix A

Definition of data variables

Demeaned growth rates
data_GDP= (output/output(-1)-mean(output/output(-1)))*100
data_CONS=(consumption/consumption(-1)-mean(consumption/consumption(-1)))*100
data_HOURS= (hours/hours(-1)-mean(hours/hours(-1)))*100
data_WAGE=(real wage/real wage(-1)-mean(real wage/real wage(-1)))*100
data_NBF=(NBF/NBF(-1)-mean(NBF/NBF(-1)))*100

Absolute values
consumption = (PCEC / GDPDEF) / LNSindex
output = (GDPC96 / LNSindex)
hours = (PRS85006023 * CE16OV /100) / LNSindex
real wage = (PRS85006103 / GDPDEF)

Source of the original data
GDPC96 : Real Gross Domestic Product - Billions of Chained 1996 Dollars, Seasonally Adjusted Annual Rate
Source: US Department of Commerce, Bureau of Economic Analysis

GDPDEF : Gross Domestic Product - Implicit Price Deflator - 1996=100, Seasonally Adjusted
Source: US Department of Commerce, Bureau of Economic Analysis

PCEC : Personal Consumption Expenditures - Billions of Dollars, Seasonally Adjusted Annual Rate
Source: US Department of Commerce, Bureau of Economic Analysis

CE16OV : Civilian Employment: Sixteen Years & Over, Thousands, Seasonally Adjusted
Source: US Department of Labor: Bureau of Labor Statistics

CE16OV index : CE16OV (1992:3)=1

LNS10000000 : Labor Force Status : Civilian noninstitutional population - Age : 16 years and over - Seasonally Adjusted - Number in thousands
(Before 1976: LFU800000000 : Population level - 16 Years and Older)
Source: US Bureau of Labor Statistics

LNSindex : LNS10000000(1992:3)=1 PRS85006023 - Nonfarm Business, All Persons, Average Weekly Hours Duration : index, 1992 = 100, Seasonally Adjusted
Source : US Department of Labor

PRS85006103 - Nonfarm Business, All Persons, Hourly Compensation Duration : index, 1992 = 100, Seasonally Adjusted
Source : US Department of Labor

NBF: Net Business Formation: index, 1967=100
Source: Survey of Current Business available at Fraser St. Louis Fed

Appendix B

Figure 5.11 shows the multipliers of the firm entry model and the baseline RBC model in response to a temporary increase in government consumption financed by lump-sum taxation for different combinations of the Frisch elasticity of labor supply and the shock persistence. The figure moreover shows the corresponding reactions of the mass of firms in the firm entry model.

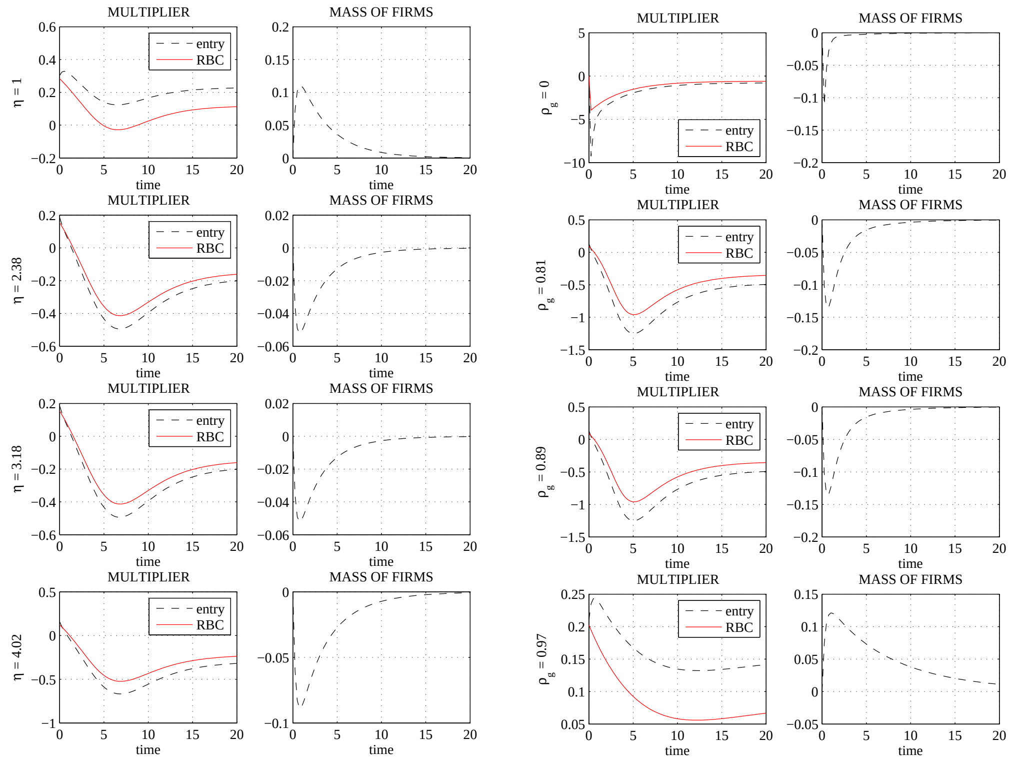

Figure 5.11: *Multipliers and the reaction of the mass of firms for different combination of* η *and* ρ_g

Figure 5.11 indicates that in all cases where the mass of firms increases in response to the fiscal demand stimulus, the multiplier of the entry model is *larger* than the multiplier in the standard RBC model with a constant extensive margin.

Appendix C

Derivation of the real marginal costs:

The cost minimization problem of a firm is given by

$$\min_{l_t, k_{t-1}} \quad \Xi = w_t l_t + r_t^k k_{t-1} - \varphi_t (z_t l_t^{\alpha} k_{t-1}^{1-\alpha} - y_t) \tag{A.5.1}$$

where φ_t is the shadow price of production.

The resulting first-order conditions are given by

$$\frac{\partial \Xi}{\partial l_t} = w_t - \varphi_t \alpha z_t l_t^{\alpha-1} k_{t-1}^{1-\alpha} = 0 \tag{A.5.2}$$

$$\Leftrightarrow \quad \frac{l_t}{k_{t-1}} = \left(\frac{\varphi_t \alpha z_t}{w_t} \right)^{\frac{1}{1-\alpha}} \tag{A.5.3}$$

$$\frac{\partial \Xi}{\partial k_{t-1}} = r_t^k - \varphi_t (1-\alpha) z_t l_t^{\alpha} k_{t-1}^{-\alpha} = 0 \tag{A.5.4}$$

$$\Leftrightarrow \quad \frac{l_t}{k_{t-1}} = \left(\frac{r_t^k}{\varphi_t (1-\alpha) z_t} \right)^{\frac{1}{\alpha}} \tag{A.5.5}$$

Aligning (A.5.3) and (A.5.5) yields

$$\left(\frac{r_t^k}{\varphi_t (1-\alpha) z_t} \right)^{\frac{1}{\alpha}} = \left(\frac{\varphi_t \alpha z_t}{w_t} \right)^{\frac{1}{1-\alpha}} \quad \Leftrightarrow \quad \varphi_t = \frac{w_t^{\alpha} (r_t^k)^{1-\alpha}}{\alpha^{\alpha} (1-\alpha)^{1-\alpha} z_t} = mc_t \tag{A.5.6}$$

Alternatively, one can express the marginal costs simply by re-arranging (A.5.2)

$$w_t = \underbrace{\varrho_t}_{mc_t} \alpha \underbrace{z_t l_t^{\alpha-1} k_{t-1}^{1-\alpha}}_{y_t / l_t} = \alpha mc_t \frac{y_t}{l_t} \tag{A.5.7}$$

or by re-arranging (A.5.4)

$$r_t^k = \underbrace{\varrho_t}_{mc_t} (1-\alpha) \underbrace{z_t l_t^{\alpha} k_{t-1}^{-\alpha}}_{y_t / k_{t-1}} = (1-\alpha) mc_t \frac{y_t}{k_{t-1}} \tag{A.5.8}$$

Inserting $Y_t^C = N_t^{\frac{\zeta_t}{\zeta_t - 1}} y_t$, $L_t = N_t l_t$, and $K_{t-1} = N_t k_{t-1}$ in (A.5.7) and (A.5.8) yields

$$w_t = \alpha mc_t \frac{N_t^{\frac{\zeta_t}{1-\zeta_t}} Y_t^C}{N_t^{-1} L_t} = \alpha mc_t \frac{Y_t^C}{L_t} N_t^{\frac{1}{1-\zeta_t}} \tag{A.5.9}$$

$$r_t^k = (1-\alpha) mc_t \frac{N_t^{\frac{\zeta_t}{1-\zeta_t}} Y_t^C}{N_t^{-1} K_{t-1}} = (1-\alpha) mc_t \frac{Y_t^C}{K_{t-1}} N_t^{\frac{1}{1-\zeta_t}} \tag{A.5.10}$$

Using the optimal real price setting equation (5.3) and $\rho_t = N_t^{\frac{1}{\zeta_t - 1}}$, we obtain (5.4) and (5.5)

$$w_t = \alpha \underbrace{\frac{\zeta_t}{\zeta_t - 1}\rho_t}_{mc_t} \frac{Y_t^C}{L_t} N_t^{\frac{1}{1-\zeta_t}} = \alpha \frac{\zeta_t}{\zeta_t - 1} \underbrace{N_t^{\frac{1}{\zeta_t - 1}}}_{\rho_t} \frac{Y_t^C}{L_t} N_t^{\frac{1}{1-\zeta_t}} = \alpha \frac{\zeta_t}{\zeta_t - 1} \frac{Y_t^C}{L_t} \tag{A.5.11}$$

$$\begin{aligned} r_t^k &= (1-\alpha) \underbrace{\frac{\zeta_t}{\zeta_t - 1}\rho_t}_{mc_t} \frac{Y_t^C}{K_{t-1}} N_t^{\frac{1}{1-\zeta_t}} = (1-\alpha) \frac{\zeta_t}{\zeta_t - 1} \underbrace{N_t^{\frac{1}{\zeta_t - 1}}}_{\rho_t} \frac{Y_t^C}{K_{t-1}} N_t^{\frac{1}{1-\zeta_t}} \\ &= (1-\alpha) \frac{\zeta_t}{\zeta_t - 1} \frac{Y_t^C}{K_{t-1}} \end{aligned} \tag{A.5.12}$$

Appendix D

Steady State Values

ρ	1.25	mc	0.92	d	0.07	Y^C	0.48	N	1.86	v	0.38
I	1.04	C	0.35	r^k	0.04	N_E	0.19	w	1.07	Y	0.55
Z	1.00	L^E	0.07	L	0.33	G	0.09	TI	0.12	I_E	0.07
τ^C	0.05	τ^d	0.36	τ^K	0.36	τ^L	0.28	K	1.74	R	1.01

Table 5.6: *Numerically computed steady state values*

6 Summary and Outlook

In this chapter, we will summarize the main results of this thesis and its contribution to the literature. Moreover, we will shortly discuss potential extensions of the presented models as well as fields for future research.

6.1 Summary

Part One: Extensions of the baseline New Keyesian model

In Chapter 1 we describe the baseline New Keynesian model. This thesis contributes to the literature by providing potential solutions for the described weaknesses. Therefore, we provide – to our mind – important model extensions of the baseline New Keynesian model in Part One and analyze new aspects of monetary and fiscal policy in Part Two.

More precisely, we develop a New Keynesian model incorporating an oligopolistic banking sector with endogenous bank entry in Chapter 2. Within this framework, we conduct an impulse response analysis and evaluate the model by comparing the generated second moments with the data. The impulse response analysis shows that the bank entry model can depict the empirically observed counter-cyclical nature of mark-ups in the loan market as well as the positive co-movement between GDP and the number of banks. We moreover find that the resulting mark-up movements in the banking sector leads to large amplification and persistence effects for the economy.[1] More precisely, we obtain accelerating effects which are significantly larger than those generated by the famous financial accelerator model of Bernanke, Gertler, and Gilchrist (1999). In contrast to the latter approach, our financial accelerator does not nest from the demand side of credits but from the supply side of credits.

The evaluation of the generated second moments in comparison with those observed in US data shows that the bank entry model performs remarkable well. More precisely, the model does not only appropriately depict the properties of key macroeconomic variables but also those of financial variables including the number of banks, the amount of aggregate loans, and the amount of loans per bank. Finally, we show that a financial activity tax and a financial transaction tax are both appropriate tools to stabilize the volatility in financial and thus in macroeconomic variables.

In Chapter 3 we provide a further contribution to the literature by developing a

[1] In particular, we obtain very large accelerating effects in the case of a monetary policy shock.

microfounded framework allowing for simultaneous entry and exit of heterogeneous firms. This chapter includes the investigation of the resulting impulse response, a second moment analysis, and an empirical part concerning a Phillips curve estimation. The impulse response analysis shows that the resulting model has several advantages in comparison with the workhorse firm entry model of Bilbiie, Ghironi, and Melitz (2007a,b). When considering a government spending shock, our model delivers more robust reactions of the mass of firms than the model of Bilbiie, Ghironi and Melitz (2007a,b) where the mass of firms only increases for small ranges of parameter values. Furthermore, Bilbiie, Ghironi and Melitz (2007b) show that in their framework an expansionary shock to monetary policy causes the mass of producers to decline.[2] In our model a decrease in the interest rate encourages entry. Moreover, the RBC specification of our model can depict both a pro-cyclical and a counter-cyclical reaction of total hours worked when varying the intertemporal elasticity of substitution. Standard RBC models can only depict a positive co-movement.[3]

The second moment analysis shows that in contrast to Bilbiie, Ghironi, and Melitz (2007a,b), our model performs better than the standard RBC model. In particular, the standard deviation of hours worked relative to GDP is very close to the empirically observed ones and that of consumption is even larger in our model.[4] Moreover, all variables do not behave too pro-cyclical. In comparison with the RBC version of our model, the introduction of sticky prices delivers slightly better results. When assuming exits to be exogenous the results become worse. An endogenous counter-cyclical tendency of firms to leave the market should thus not be neglected.

Finally, we estimate the resulting CPI Phillips curve with the generalized method of moments. It turns out to be a function not only of expected future inflation and the labor share but also of the change in the mass of producers. The estimation shows that the impact of the change in the mass of producers on CPI inflation is highly significant and reacts in line with our theoretical findings. Moreover, we show that the CPI Phillips curve becomes flatter in an inflation/labor share-space in comparison with the standard New Keynesian Phillips curve. This implies that the introduction of an endogenous mass of producers causes the impact of the labor share on inflation to decrease as there occur additional effects from changes in product variety.

Part Two: Monetary and Fiscal Policy Analyses

In *Part Two* consisting of Chapter 4 and 5, we contribute to the literature by providing new aspects of monetary and fiscal policy. More precisely, the aim of Chapter

[2] This however conflicts with the empirical findings of Bergin and Corsetti (2008) and Lewis (2009).

[3] A positive co-movement between total hours worked and TFP is however ad odds with the widespread agreement in the empirical literature that there exists a negative correlation between hours worked and GDP.

[4] In the standard RBC model hours worked and consumption behaves too smooth relative to output [see King and Rebelo (1999)]. This problem remains in the firm entry model of Bilbiie, Ghironi, and Melitz (2007a,b).

4 is to solve the inconsistency problem à la Barro and Gordon within a standard New Keynesian model and to derive time-consistent interest rate rules of Taylor-type. More precisely, we implement the famous Kydland/Prescott - Barro/Gordon approach in a static approximation of the canonical New Keynesian model. We thus consider a positive output gap target in the social loss function. Within this framework, we are able to discuss both the commitment vs. discretion debate of the New Keynesian literature and the time-inconsistency problem of Barro and Gordon (1983a,b) in a unified framework.

We first show that in line with conventional wisdom, commitment strategies can be advantageous to discretionary monetary policy. Second, we show that these policy rules cause the monetary authority to deviate from their announcements since the re-optimization yields a welfare gain. By assuming a long-run planning horizon of the central bank and that the monetary authority looses its reputation for a certain period of time when switching over to inconsistent policy, we find a continuum of stable interest rate rules of Taylor-type. In contrast to the Kydland/Prescott-Barro/Gordon approach, implementing a monetary rule such that the cost and benefit resulting from inconsistent policy coincide, is however not optimal. Instead, the solution can be enhanced by moving into the stable area where the net gain of inconsistent monetary policy behavior is negative. By introducing an additional term in the social loss function concerning interest rate stabilization, the continuum of stable Taylor rules becomes larger. This implies that the reputation of the monetary authority naturally improves when it is also concerned about stabilizing the interest rate. Third, we find that under a standard calibration including a time preference rate equal to the long-run interest rate, the standard Taylor rule is time-consistent for the cost-push shock as well as for simultaneous supply and demand shocks. Fourth, in the mass of stable Taylor rules, there does not exist a specific rule which minimizes the social loss.

In Chapter 5 we estimate an RBC model with capital in production and endogenous firm entry using Bayesian techniques. Within this framework, we investigate the macroeconomic effects of different fiscal interventions. This is our last contribution since the recent theoretical literature only analyzes the impacts of fiscal stimuli on standard economic measures of economic activity (GDP, employment, capital investment) but neglects their impact on the development of the extensive margin, i.e. the mass of firms. We demonstrate that the extensive margin is a crucial dimension for evaluating fiscal policy since it can significantly accelerate and decelerate the impacts of fiscal stimuli. More precisely, we find that if in response to a fiscal stimulus the mass of firms increases, fiscal multipliers are amplified. If, however, the mass of firms declines, the reaction of the extensive margin dampens the impact on economic activity. This result remains robust to different fiscal interventions such as tax cuts and fiscal packages financed by distortionary taxation.

We show that a pure demand stimulus and a consumption tax cut financed by lump-sum taxation lead to small fiscal multipliers since these interventions result in an additional crowding-out effect of investment in new firms. By contrast, labor and dividend tax cuts generate significantly larger multipliers since these fiscal interventions both induce a crowding-in of consumption, of investment in existing capital, and of investment in new product creation. The latter effect in turn leads to a further amplification via an increase in the mass of products.

Considering the case that the increase in government consumption is financed by distortionary income taxation, we find that the tax hike causes fiscal multipliers to become strongly negative which is even amplified by a decreasing mass of firms. This result is consistent with the findings of Uhlig (2010) in the case of distortionary labor taxation. If the demand stimulus is financed with higher consumption taxes, the fiscal multiplier is approximately zero.

6.2 Outlook

In our opinion, the contributions of this thesis especially give rise to four blocks of future research: monetary policy issues, frictional labor markets, combinations of the presented approaches, and a closer examination of financial markets.

Monetary Policy Issues

To highlight the role of an endogenous mass of firms for the impacts of different fiscal packages on real economic activity, we employ a Real Business Cycle model with firm entry in Chapter 5. Thus, the applied framework does not allow for any role of monetary policy. The interplay of monetary and fiscal policy in a New Keynesian model with firm entry may thus be a promising area for future research.[5] Moreover, the simplicity of our model precludes a thorough quantitative examination of the impacts of the ARRA (American Recovery and Reinvestment Act) fiscal stimulus packages. Future research should be to conduct a Bayesian estimation of a DSGE model with several nominal and real frictions as in Cogan et al. (2010) as well as endogenous firm entry to quantify the fiscal accelerator discussed in the chapter at hand. In particular, this analysis should include rule-of-thumb consumers as outlined in Galí, López-Salido, and Vallès (2007) to increase the size of the fiscal multiplier.

Frictional Labor Markets

Throughout this thesis, we assumed labor markets to be complete as in the baseline New Keynesian and RBC model. Naturally, this is a simplifying assumption

[5] See Linnemann and Schabert (2003) for the corresponding investigation within the baseline New Keynesian model.

but it implies that there does not exist any involuntary unemployment in the economy. However, the recent literature highlights the role of *frictional labor markets* for describing macroeconomic phenomena. In our opinion, four approaches are worth mentioning in this context. First, the theory of efficiency wages where due to moral hazard and a principal-agent problem, employers keep the wage above the corresponding market clearing level. Seminal work reaches back to Shapiro and Stiglitz (1984). Second, the insider-outsider theory initiated by Lindbeck and Snower (1986, 1988) where insiders, i.e. employees, are protected by the existence of hiring and firing costs. The third approach is the famous search and matching theory. Basically, this theory was initiated by Mortensen (1982) and Pissarides (1984), although it actually originates from the pioneering work of Stigler (1962), Friedman (1968), and Phelps (1968). The search and matching theory has become the workhorse model for analyzing (un)employment dynamics in DSGE models [see e.g. Mortensen and Pissarides (1999), Rogerson, Shimer, and Wright (2005), Trigari (2006, 2009), or Krause and Lubik (2007)]. However, a major problem of this class of models is that it cannot appropriately depict the empirically observed volatilities in labor markets [see Shimer (2005) or Barnichon (2009)].[6] Therefore, Brown, Merkl, and Snower (2010) provide an alternative framework where the employment decision is "incentive-based". This is the fourth approach we would like to mention. Beside a complete microfoundation, this framework offers an approach which can appropriately depict the empirically observed volatilities of the unemployment rate, vacancies, the job finding rate, and the separation rate.

Combinations of the Derived Approaches

A further interesting extension would be to *combine* the frameworks with an endogenous mass of firms as developed in Chapter 3 or as sketched in Chapter 5 with the bank entry model derived in Chapter 2. This gives rise to further amplification and persistence effects. For instance, we show in Chapter 2 and 3 that an expansionary technology shock in insolation leads to an increase in the mass of banks and in the mass of firms, respectively. Since the increase in the mass of banks causes the marginal costs of firms to decrease this would offer additional profit opportunities for potential firms leading to an increase in the mass of firms in a combined approach with simultaneous firm *and* bank entry. This in turn would lead to additional profit opportunities for banks since new firms also ask for loans leading to an increase in the mass of banks, etc. This mechanism would generate a strong amplification effect.

Moreover, this framework could depict an interesting interplay between the extensive margins in the real and the financial sector. Additionally, this framework would

[6] In addition, the assumption of the existence of a matching function is totally ad hoc and seems naturally to be dubious in light of the Lucas Critique. Moreover, the search and matching framework does only depict search unemployment.

allow for a closer investigation of investment decisions since it would offer a distinction between investment in real and financial assets and – by including capital in production – investment in physical capital as well. In Chapter 5 we show that there can exist a substitution relation between investment in physical capital and investment in new firms. When additionally considering investment in new banks, there would occur a further substitution opportunity for households. It would be interesting to investigate how shocks in the real or financial sector affect these investment decisions in such a framework.

More Complex Financial Frictions

Moreover, the assumed banking sector in Chapter 2 is kept very simple to depict the pure effects of the non-stationary price-cost margins of banks. It seems to be a fruitful extension of our analysis to incorporate a more complex and realistic banking sector. A possible extension would be for instance to follow Angeloni and Faia (2010) and integrate a banking market as outlined in Diamond and Rajan (2000, 2006). In particular, this framework allows for *uncertainty* in project outcomes and consequently introduces *risk* in the bank's balance sheet decisions. Within this framework Angeloni and Faia (2010) study monetary policy transmissions and the interplay between monetary policy and bank capital regulations.

For the sake of simplicity, our bank entry model moreover does not incorporate an *interbanking* market, i.e. banks only provide credits to firms and *not* to other banks. A framework considering interbank lending in a DSGE model is for instance provided by Goodfriend and McCallum (2007). However, the authors assume – for the sake of simplicity – that banks act under perfect competition and that the number of banks is constant. Therefore, it would be an interesting approach to incorporate oligopolistic banks in their framework to investigate how the development of non-stationary oligopolistic mark-ups affects interbank lending.

"In recent decades, asset booms and busts have been important factors in macroeconomic fluctuations" [Bernanke and Gertler (2001, p. 253)]. After the appearance of the current financial crisis in 2007, this claim has become even more important. In order to depict booms and busts in a monetary model, Bernanke and Gertler (1999) extend the BGG framework by adding *exogenous* asset price bubbles and investigate interesting monetary policy issues in this environment. In the last decade, this framework naturally has become very popular [see amongst others Gilchrist and Leahy (2002)]. In particular, we want to dignify the work of Lengnick and Wohltmann (2010) who extend the BGG framework by a high-frequency asset market in the spirit of Dieci and Westerhoff (2004) to allow for *endogenous* asset price bubbles. In our opinion, this is a very promising field for future research.

We do not know how monetary macroeconomic models will evolute in the next decades. However, we claim that events as the current financial crisis call for models with endogenous asset booms and busts in combination with the developed frameworks of this thesis – especially endogenous bank or/and firm entry and exit.

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Curriculum Vitae

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Personal

Born on April 25, 1983 in Kiel

Education

Doctoral Programme “Quantitative Economics”, Christian-Albrechts-Universität zu Kiel, since October 2007.

Diplom-Kaufmann (Diploma in Business Administration), Christian-Albrechts-Universität zu Kiel, December 2008.

Diplom-Volkswirt (Diploma in Economics), Christian-Albrechts-Universität zu Kiel, July 2008.

Abitur (General Higher Education Entrance Qualification), Humboldt-Schule Kiel, June 2002.

Research Experience

Research and Teaching Assistant, Christian-Albrechts-Universität zu Kiel, Department of Economics, Professorship of Macroeconomics (H.-W. Wohltmann), since April 2008.

Student Assistant, Christian-Albrechts-Universität zu Kiel, Department of Economics, Professorship of Macroeconomics (H.-W. Wohltmann), June 2006 – March 2008.

Teaching Experience

Übung: Advanced Macroeconomics SS 08

Übung: Dynamische Simulationen WS 08/09, WS 09/10, SS 10

Übung: Geld- und Kredittheorie SS 10

Übung: Grundzüge der makroökonomischen Theorie WS 08/09, WS 09/10

Übung: Makroökonomik I SS 08

Übung: Makroökonomische Transmissionsmechanismen SS 09

Übung: Stabilisierungspolitik WS 09/10, WS 10/11

Seminar: Makroökonomisches Seminar WS 09/10

Seminar: Geld- und Kredittheorie WS 08/09

Seminar: Neue Makroökonomik WS 10/11

Seminar: Stabilisierungspolitik SS 09, SS 10

Working Papers

"Banks, Oligopolistic Competition, and the Business Cycle: A New Financial Accelerator Approach", Economics Working Paper 2011-02, Department of Economics, Christian-Albrechts-Universität zu Kiel.

"Fiscal Stimulus in a Model with Endogenous Firm Entry" (with R. C. Winkler), November 2010, Munich Personal RePEc Archive (MPRA) Paper No. 26829.

"Barro-Gordon revisited: Reputational equilibria in a New Keynesian Model" (with H.-W. Wohltmann), March 2010, Economics Working Paper 2010-04, Department of Economics, Christian-Albrechts-Universität zu Kiel.

"Firms' Heterogeneity, Endogenous Entry, and Exit Decisions", Dec. 2009, Economics Working Paper 2009-11, Department of Economics, Christian-Albrechts-Universität zu Kiel.

"Banks and Early Deposit Withdrawals in a New Keynesian Framework", Oct. 2009 (first Version: Dec. 2008), Economics Working Paper 2009-08, Department of Economics, Christian-Albrechts-Universität zu Kiel.

Conferences and Workshops

Presentation at the Fifth EBIM Doctoral Workshop on Economic Theory, Bielefeld, Nov. 2010

Presentation at the Annual Meeting of the German Economic Association (Verein für Socialpolitik), Kiel, Sep. 2010

Presentation at the 25th Annual Congress of the European Economic Association, Glasgow, Aug. 2010

Presentation at the XVth Spring Meeting of Young Economists, Luxembourg, April 2010

Presentation at the 3rd RGS Doctoral Conference in Economics, Bochum, Feb. 2010

Presentation at the Annual Meeting of the German Economic Association (Verein für Socialpolitik), Magdeburg, Sep. 2009

Presentation at the Conference on Macroeconomics: Theory and Applications, Brunel University, London, July 2009

Presentation at the 5th Macroeconomic Research Meeting, IAW Tübingen, March 2009

Participation at the EES Kick-off Workshop: The Labor Market and the Business Cycle, IfW Kiel, March 2009

Participation at the 3rd Workshop Macroeconomics and Business Cycles, ifo Dresden, Nov. 2008

Awards and Grants

Möller Fund Travel Grant 2010

EBIM Travel Grant 2010

Möller Fund Travel Grant 2009

Holsteiner Studienpreis 2008

Erich-Schneider-Preis 2008

Memberships

European Economic Association

Verein für Socialpolitik (German Economic Association)

European Area Business Cycle Network

Referee Service

Economic Modelling

Kiel, March 07, 2011

Eidesstattliche Erklärung

Ich erkläre hiermit an Eides Statt, dass ich meine Doktorarbeit "On the Macroeconomic Implications of Firm Dynamics, Banking, and Reputation" selbständig und ohne fremde Hilfe angefertigt habe und dass ich alle von anderen Autoren wörtlich übernommenen Stellen, wie auch die sich an die Gedanken anderer Autoren eng anlehnenden Ausführungen meiner Arbeit, besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert habe.

Kiel, 07. März 2011

(Alexander Totzek)